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USAGE OF STRUCTURAL EQUATION MODELING AND ANALYTIACL HIERARCHY PROCESS APPROACH TO SELECT INFORMATION TECHNOLOGY VENDOR

by

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DECLARTION OF THESIS

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ABSTRACT

Progressive change is an accurate way to describe the advancement of information technology (IT) throughout the 1990s. As IT continues to evolve, the ways in which companies do business are also changing. The emergence of the Internet as a business venue, the growing percentage of consumers accessing the Web, and the increasing number of households equipped with a PC or other Web-access device are speeding IT's rate of change. The industries especially banking and financial services industries (BFSI) are heavily supported by IT and technology vendor for their service oriented business. It indicates that choosing the right vendor remains a critical success factor for every enterprise's business success. Selection of the best possible set of vendors not only allow organisations to downsize and utilise resources more effectively, but also allows them to take advantage of the capabilities and technologies of the vendors. The vendor selection process can be a very complicated and emotional undertaking if the approach from the very beginning is not known. The purpose of this research is to identify the required criteria for selecting the best vendor for information technology (IT) process and provide a vendor selection model including these criteria by using the structural equation modeling (SEM) and analytic hierarchy process (AHP). To demonstrate the above model and also, to arrive at vendor selection scores, the vendor selection for mobile banking application was considered as an example. The developed model is a generic one considering the global economic turmoil and the amount of pressure on banking & financial services industries (BFSI), where IT is the backbone of the BFSI; In any future studies the model could be applied in making other strategic decisions like IT outsourcing, ERP (enterprise resource planning) implementation vendor selection etc.

ABSTRAK

Perubahan progresif adalah satu cara yang tepat untuk menggambarkan kemajuan teknologi maklumat (IT) di seluruh tahun 1990-an. Sebagai IT terus berkembang, cara-cara di mana syarikat menjalankan perniagaan juga berubah. Kemunculan Internet sebagai tempat perniagaan, peratusan pengguna yang mengakses web yang semakin meningkat, dan peningkatan bilangan isi rumah yang dilengkapi dengan PC atau peranti akses Web-lain mempercepatkan kadar IT perubahan. Industri perkhidmatan terutamanya perbankan dan kewangan industri (BFSI) banyak disokong oleh IT dan vendor teknologi untuk perniagaan berorientasikan perkhidmatan mereka. Ia menunjukkan bahawa memilih vendor yang tepat terus menjadi faktor kejayaan yang kritikal bagi setiap kejayaan perniagaan perusahaan. Pemilihan set yang terbaik mungkin vendor bukan sahaja membolehkan organisasi untuk mengecilkan dan menggunakan sumber dengan lebih berkesan, tetapi juga membolehkan mereka untuk mengambil kesempatan daripada keupayaan dan teknologi vendor. Proses pemilihan vendor boleh menjadi satu usaha yang sangat rumit dan emosi jika pendekatan dari awal-awal lagi tidak diketahui. Tujuan kajian ini adalah untuk mengenal pasti kriteria yang diperlukan untuk memilih penjual terbaik untuk proses teknologi maklumat (IT) dan menyediakan model pemilihan vendor termasuk kriteria ini dengan menggunakan pemodelan persamaan struktur (SEM) dan proses hierarki analitik (AHP). Untuk menunjukkan model di atas dan juga, untuk tiba di skor pemilihan vendor, pemilihan vendor untuk permohonan perbankan mudah alih adalah dianggap sebagai contoh. Model yang dibangunkan adalah satu generik mengingati kegawatan ekonomi global dan jumlah tekanan pada perbankan & kewangan industri perkhidmatan (BFSI), di mana IT adalah tulang belakang yang BFSI; Dalam mana-mana kajian masa depan model yang boleh digunakan dalam membuat keputusan strategik yang lain seperti penyumberan luar IT, pelaksanaan pemilihan vendor ERP (perancangan sumber perusahaan) dan lain-lain.

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LIST OF ABBREVIATIONS

AHP	Analytical Hierarchy Process
ANN	Artificial Neural Network
ANP	Analytic Network Process
BFSI	Banking & financial services industries
CFA	Conformity Factor Analysis
CFI	Comparative Fit Index
CMM	Capability Maturity Model
DEA	Data envelope Analysis
DF	Degrees of Freedom
ERP	Enterprise Resource Planning
GFI	Goodness-of-Fit
IFI	Incremental Fit Index
ISO	International Standards Organisation
IT	Information Technology
MAUT	Multiple Attribute Utility Theory
MCDM	Multiple Criteria Decision Making
NASDAQ	National association of securities and dealers automated quotation
R&D	Research and Development
RFI	Request for information
RFP	Request for proposal
RMSEA	Root mean square error of approximation
SEM	Structural Equation Modeling
SA	Sensitivity Analysis
TQM	Total Quality Management
USA	United States of America

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter represents background in the first section wherein the importance IT and IT vendor has been discussed followed by brief history which is a brief background of this research and which addresses the research motivation as well. The second section provides the identification of research gap and scope of research. The subsequent sections discuss about objectives, research questions, problem statement and contributions; finally the structure of the thesis. The researcher has frequently used the reference of BFSI (banking & financial services industry), IT (information technology) and outsourcing in the whole research, as this research has considered the case of vendor selection for mobile banking application, which is based on information technology.

1.2 Background

This section discusses about the importance of information technology and technology vendor; it also discusses about the importance of vendor selection method and discusses about the history of vendor selection and different criteria for vendor selection, which are popular and have been studied in various literature related to vendor selection.

1.2.1 Importance of information technology & vendor selection

Information technology is considered extremely important for the revenue generating operations of divisions of the organizations. Technology has transformed the way people obtain financial services today. Telephone banking, debit and credit cards, and automatic teller machines are commonplace, and electronic money and banking are evolving. This shows that technology is clearly shifting away from support and administrative function to the more mainstream and strategic functions. The search for new vendors is a continuous priority because of not only to run the operation, but also to upgrade the variety and type of their service offerings. Information technology has opened up new markets, new products, new services and efficient delivery channels for banking industry. However, the expected professionalism of vendor selection in BFSI is far from common practice. A majority of the relatively few models that have been developed for vendor selection are based on rather simplistic perceptions of decision making processes and do not seem to address the complex and unstructured nature and context of many present-day IT vendor selection. Several issues that may complicate the selection process such as incomplete information, additional qualitative criteria and imprecise preferences are often not taken into account. Moreover, considering banking application is a very complex; involve several applications integrations and technologies a right vendor is not just a vendor but a strategic business partner in long run.

Whilst considering all the above, it is evident that need of a technology vendor is eminent and thereby vendor selection is an important activity in BFSI; but unfortunately this is a semi-structured management problem today. Vendor selection has always been a complex process as various criteria, known and half known are involved in making a decision (Jitender and Nirjhar, 2010). The BFSI is going through the biggest ever challenges today and during this phase the right selection of technology vendor will not only help them to turnaround the business but will reduce the operating cost.

Especially mobile banking, which is considerably new technology, and gaining popularity day-by-day, but still has not appealed the mass mobile users population because of several reasons and one among that is lack of confidence on online transaction, which can be addressed by selecting the right technology vendor. This has motivated the researcher to develop a model involving multi-criteria decision making for vendor selection for a specialized banking application.

1.2.2 Brief history

The banking industry which started with a simple form of banking was once practiced by the ancient temples of Egypt, Babylonia, and Greece, which loaned at high rates of interest the gold and silver deposited for safekeeping to today's sophisticated financial transactions where information technology is the spine. Through the introduction of IT related products in internet banking, electronic payments, security investments, information exchanges (Berger, 2003, Shirley and Sushanta, 2006), banks now can provide more diverse services to customers with less manpower. The banks are for all good reasons thereby very careful in selecting their technology vendors, who help them in developing the IT applications and customize the applications to the various needs of the banks.

Thus selection of a vendor is a critical and complex multi-objective, multi criteria decision making problem. Even though, quite a few vendor selection models are available in the literature, in this research, an attempt has been made to develop a composite model using SEM and AHP to attain the vendor selection score. This research focuses on the criteria that influence vendor selection and the model has been built based on those criteria.

An extensive study of literature, white paper, journals, discussion with professional in the related field has provided the researcher an insight about various methods and selection criteria have been studied so far for vendor evaluation. This has become the starting point of this research.

There are several criteria that affect the vendor selection process. In regard to vendor selection for BFSI, the technical elements and past experience or reference clients may affect the vendor selection process. The number of vendors to be selected depends on the sourcing strategy that a firm follows. If the firm is in favour of single sourcing, a single vendor is to be selected. If, on the other hand, the firm follows a multiple sourcing strategy, then more than one vendor is selected. The initial observation was that 29 major criteria listed in table 1.1 based on their rank in the selection process, which was discussed in most of the journals and literature studied. The * marked in the table are the criteria that appeared in Dickson's (1966) research.

Table 1.1 Rank of vendor selection criteria

No.	Criteria
01	Quality (*)
02	Delivery (*)
03	Cost (*)
04	Production facility and capacity (*)
05	Flexibility and reciprocal arrangement (*)
06	Technical capacity and support (*)
07	Technical services and follow up (*)
08	Information technology and communication system (*)
09	Financial status (*)
10	Innovation and R & D
11	Operating controls (*)
12	Quality system
13	Management and organization (*)
14	Personnel training and development (*)
15	Product reliability/stability
16	Packaging & handling ability
17	Customer relationship
18	Warranties and claim policies (*)
19	Procedural compliance (*)
20	Customer satisfaction and impressions (*)
21	Attitude and strategic fit (*)
22	Labour relations record (*)
23	Economical aspect
24	Desire for business(*)
25	Environmental and social responsibility
26	Data security
27	Domestic political stability
28	Vendor culture
29	Terrorism risk

It was observed through different study and interaction with the professionals in the relevant field and through researcher own work experience that most of the banks follow the traditional evaluation process of selection vendor which consists of:

- Response to a Request for Information (RFI) or Request for Proposal (RFP)
- A product demonstration
- A Proof-of-Concept
- A list of customer references
- Product documentation
- Evaluation software
- Product roadmap information
- Competitive comparison documents
- A live, telephone, or web-based meeting to have a discussion and ask questions

Tanmoy et al, (2011) has stated that in vendor selection procedure, there is a need for developing a systematic vendor selection process of identifying and prioritising relevant criteria and evaluating the trade-offs between technical, economic and performance. In this research, the researcher has reviewed some important criteria based on white paper, journal and literature study and also though discussions with professional related to technology industry and relevant to technology vendor selection, to compare one vendor over others during the vendor selection;

- Professional Technical Support, with service level commitments, escalation processes, and 24 X 7 availability if required
- High-quality product documentation
- Professional training, including customized training and onsite training at customer facilities if so desired
- A professional development team and development methodology, to ensure sound technology architecture and enterprise deploy ability

- Product management to continually align product direction and priorities to customer requirements and market needs
- Intellectual property indemnification, to avoid any perceived risks associated with the use of open source software.

However, this has been discussed in details in literature review chapter.

1.3 Identification of research gap

One of the most critical gaps related to baking vendor selection is to what criteria of the vendor will influence the selection decision. However, the gaps which have been found in different research and journals are stated as below:

- Most of the studies are available pertaining to technology vendor for banking industry is subjective in nature and based on human judgment. It has been discussed in the previous section that a lot of banks in South East Asia still follow the traditional method of vendor evaluation through RFP (request for proposal) and human judgment method.
- Though the importance of vendor selection and its strategies have been studied in conceptual models by earlier researchers, the relationship between various criteria in vendor selection and the effect of one over the other has not been carried out so far systematically.
- There are not many research papers are available which quantitatively weighs and measures potential vendors against key criteria in respect to banking industry for successful vendor selection. Most of the available research targets the supply chain related work.
- There is no research available on using SEM and AHP model to select a technology vendor.

The problem provides an opportunity to work on BFSI and develop a generic model using SEM-Approach and AHP for vendor selection. Through this research, the researcher has developed a model to measure the vendor selection. The measure will be composed in such a way, that it represents multiple dimensions. The vendor selection score will be derived from the developed composite model for any number of vendors and will facilitate suitable suggestions to enable more effective decision processes.

1.4 Objectives of the research

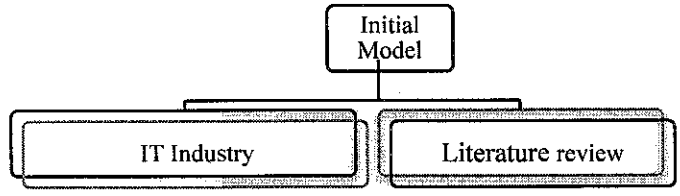
The reason for vendor selection is to determine the optimal vendor who offers the best all-round package of products and services for the customer (Swift & Gruben 2000) and the greater use of advanced vendor selection and monitoring practices tends to increase profitability and product quality (Ittner *et al* 1999).

A qualified IT vendor is the key element in reducing organisations' cost; facilitate the organisation to focus on core activities and provide business intelligence to increase their market share. In the light of the importance and the growing complexity of vendor selection, the overall objective of this research is:

I. Identify and comprehend the various criteria and the sub criteria that will influence vendor selection to be more effective.
II. Developing a vendor selection score model by using SEM and AHP.
III. Applying the developed model to arrive at vendor selection final score in a real life example.

The above objectives are illustrated in below figure 1.1, which is the framework of this research.

Step 1



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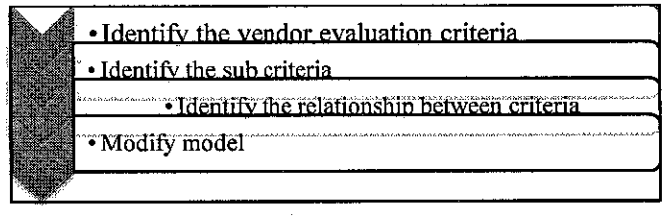

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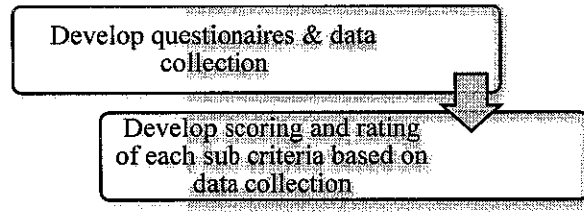

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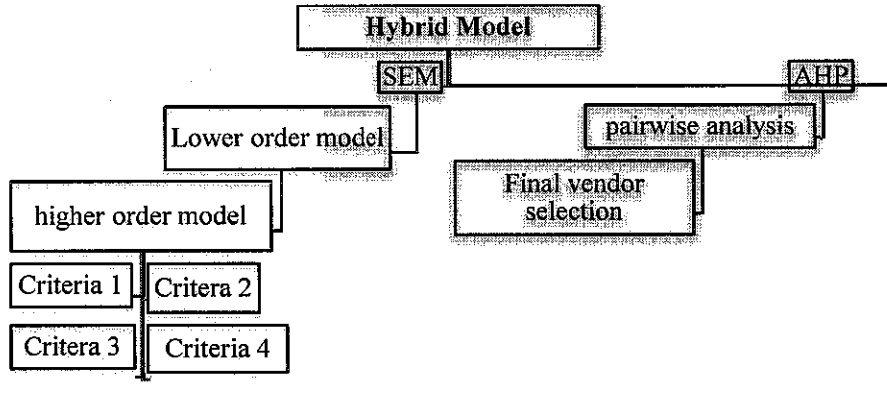

Figure 1.1 Research Framework

Based on the relevant gaps identified in various literatures, this thesis is oriented towards the response to the following central research questions:

I. What is mobile banking and how does mobile banking can add value to retail banking?
II. What is the purpose of vendor selection in retail banking?
III. How to identify the various criteria and the sub criteria that will influence vendor selection in BFSI related to information technology?
IV. How to develop an effective vendor selection score model?
V. How the developed model will work in a real life scenario?

In order to address these research questions, the following immediate objectives were formulated.

- ✓ First, an understanding of internet and mobile banking and its contribution to banking industry. This understanding requires case studies and study on mobile banking implementation method and technology involved.
- ✓ Secondly, the need of a vendor of and a comprehensive understanding of the existing different conceptual framework governing to vendor selection processes. This understanding is required in order to properly design the associated empirical research project, and to identify a vendor selection process that will help banks to identify their right vendor for IT application development.
- ✓ Third, to identify and consolidate different criteria and sub criteria associated with vendor selection and more relevant to mobile banking application. In this process the researcher has collected information about different banks deal with vendor selection processes related to IT vendors. Pursuing this goal should contribute to uncover the underpinning principles of the procurement system and complete the necessary inputs to answer the first research question.

- ✓ Fourth, based on the gaps and casual relationships identified through empirical research, formulate the new model to effectively manage vendor selection.
- ✓ Finally, the developed model will be applied to arrive at vendor selection final score in a real life example.

1.5 Problem statement

Vendor selection is a multi-criteria problem since implementing a new solution or eliminating inferior solutions from the feasible set to upgrade a modern version, require considering all possible settings for the criteria selected. The more number of criteria included in the selection, the harder it gets to obtain a solution. Although the selection and evaluation criteria usually vary from company to company, it is not surprising to observe commonality of some of the criteria like organisation size, reference clients, delivery, cost etc. which are generic and applicable to all industries. The number and the nature of the criteria employed in the vendor selection process vary with the type of the business, type of the product and the strategic approach employed by the company. All these compel the buyer (e.g. banks) to collaborate with vendor (e.g. IT vendors) from the early phase of technology development, and it begins with the correct choice of vendors (Wagner 2010), and there are not a lot of efficient techniques or algorithms address this problem. The conventional methods that are being used for vendor selection like categorical or key factoring rating model, cost ratio model, weighted cost methods etc. are very subjective in nature. They are subjective because buyer assigns values to various criteria that are involved in vendor selection and the value varies from one buyer to another for the same vendor. Selection is based on a broad comparison of vendors using a common set of criteria and measures. However, the level of detail applied in examining potential vendors may vary depending on firm needs.

The ultimate goal of selection is to identify the optimal vendors, which will not necessarily the vendor offering the best technical service, or that with the lowest price, or that with the shortest delivery time. Thus, firms must consider various criteria in attempting to distinguish among items offered by potential vendors.

However, the assessment criteria frequently conflict, and it is often impossible to identify a vendor that excels in all areas. Additionally, some of the criteria are quantitative and some are qualitative. So the need for methods / algorithms that are more objective in nature and that involve assigning common set of values to selection criteria, to be used. Thus, obviously there is a need for a method that can capture both subjective and objective evaluation measures.

1.6 Scope of research

To investigate the problem discussed in earlier section, the researcher has considered the selection of mobile banking application vendor for retail banking sector. In order to understand the mobile banking application and its advantages and growth, the researcher has done thorough study of different journals related to mobile banking application and discussed with IT managers and professionals, who are directly involved in developing or maintaining such application for different banks. This has helped the researcher to understand the importance of mobile banking vendor and to a great extent to identify the relevant criteria for this technology vendor selection.

The use of mobile technology has been heralded as a potential revolution in the retail banking sector, enabling bank customers to manage their financial affairs regardless of their location. The ubiquitous nature of mobile devices and services, and the ability of mobile banking services to reduce overall operational costs, streamline operations, and expand customer base are expected to boost prospects in the industry.

Increasing adoption of mobile phones among general consumers, particularly among the younger generation in the 18-34 years age group and rapid rise in demand for mobile payments are expected fuel demand for mobile banking services. Global mobile banking customer base are expected to reach 1.5 billion by 2015 (Mobile payment magazine, 2010). Mobile usage has seen an explosive growth in most of the Asian economies like India, China and Korea.

For several years, commercial banks in Malaysia have tried to introduce mobile banking systems to improve their operations and reduce transaction costs (Hanudin et al. 2008, Amin & Muhammad 2007). Apple's initial success with iPhone and the rapid growth of phones based on Google's Android (operating system) have led to increasing use of special client programs, called apps, downloaded to the mobile device.

The following case studies on Malaysian banks have helped the researcher to have more insight about the practical effect of mobile banking; the case studies were discussed with the relevant application vendor to understand their view on mobile banking and refining the above criteria.

- Agro Bank is a local Development Bank in Malaysia has the responsibility of servicing its customers within agrarian communities, which are typically located in rural and remote areas. They have to be able to provide basic banking facilities and services so as to meet the financial needs of their constituents. With such customers, the Bank realized that a Mobile Banking solution was required so that they are able to deliver a banking experience that is approximate to what can be obtained from the conventional bank branch. Bearing in mind the lack of communications infrastructure in these areas, such a solution faced daunting challenges. Tricubes, a system integrator provided a mobile computer with banking applications akin to that of a Branch Delivery System. It is able to undertake operations such as opening of bank accounts, accepting monies for deposits, loan repayments and facilitate merchant bill payments. There is also a barcode scanner to allow for automatic data reading of the bills. With Mobile Banking, the bank has improved on its customer service and is now able to facilitate clients beyond the confines of the bank branch (Reference: http://www.tricubes.com)
- BIMB (Bank Islam Malaysia Berhard) was introduced in 1983 in order to provide Shariah compliant financial products and services to Malaysians, regardless their religion. Mobile banking was introduced by BIMB in July 2004 for three main reasons.

First, it offers better banking products and services by providing the bank customers with an added convenience, flexibility and cost-saving option in conducting their banking transactions. Second, this new service complements the purpose of BIMB existing e-banking channels, namely ATM network and Internet banking services. Third, BIMB also believes that mobile banking services will contribute towards cost-saving in its operations by diverting the bank customers from banking halls to this new service, thus enabling to save the operating cost or opening new service outlets.

1.7 Research contributions

The main contributions of this research are discussed in the following points:

- The main focus of this research is to address two issues, vendor selection criteria relevant to mobile banking application, and development of a unique model for vendor selection. The technology vendors are the strategic partners of the bank, and thereby a proper methodology to select the right vendor, will not only help the banks secure the proper service, but will form a long term business alliance with the vendor.
- The proposed model is a unique one as it combines the all the advantages approach of SEM and AHP. The researcher has not come across to any study, which combines the two said model to determine the technology vendor.
- Vendor selection though a very important aspect in banking industry, but spreadsheet or human judgment based. Thus the proposed model represents a sufficient tool which will strongly accelerate the vendor selection as well as improving business process within the organisation.
- What if analysis is used as a common and beneficial technique that helps pointing out the reliability and effectiveness of the proposed model, what-if-analysis allows managers/decision makers to change a decision variable and then immediately get a new result for an outcome variable.

The proposed model has shown high degree of sensitivity towards any changes in the input variables. Considering the case study of the new hybrid model, which has been proposed in this research, it can obviously emphasise its reliability and sensitivity.

1.8 Outline of thesis

This thesis is structured in five chapters.

- Chapter one gives an introduction this research paper; this covers a brief background wherein the importance of vendor selection and a brief history of vendor selection have been discussed; the problem statement was discussed where case studies on mobile banking on two Malaysian banks have been studied. The identification of research gaps, objectives and the research contribution were also explored in this chapter.
- Chapter two provides a review of literature in relation to this subject area. This contains critical evaluation and discussions of other related research. Along with discussions of what has been studied previously in line with the subject of vendor selection, the issues and challenges faced by the other researchers and a summary literature review.
- Chapter three is the method of investigation. This chapter describes the general framework of the vendor selection It also discusses the research methods, and the justification of using SEM and AHP.
- Chapter four is the analysis of the data and a discussion of the results. This chapter includes a detailed description of the results obtained followed by discussions, analysis and interpretation of the data obtained.
- Chapter five is the final chapter in the thesis, which is the result & discussions. This chapter summarises the results and findings and recap the main contributions of the work completed. This also includes the suggestion for future work and possible improvement.

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter overview

This chapter provides a broad study of the vendor selection criteria; various methods and models in vendor selection are discussed too. This chapter discusses the complexity of the selection process. The different criteria and sub criteria have been studied and discussed in this chapter, which determine the vendor selection. This chapter provides a critical evaluation and discussions of other related research studies; that include, discussions of what has been done, the issues and challenges faced by other researchers and the summary of the knowledge from the literature review.

2.2 Introduction

The review was done on the literatures and journals published after Dickson's (1966) classic research. This was necessary to understand the changing scenarios of vendor selection and the different methodologies been adopted by earlier researchers in last four decades. There are several keywords associated with the vendor selection. The terms "supplier selection", "vendor selection" and "technology vendor selection", "IT outsourcing" is frequently and interchangeably used in the literature. A number of criteria have been selected, which constitute the basis of the literature review.

These are generally grouped in accordance with whether they relate to the vendor, the product or the purchasing organisation (Wagner *et al* 1989; Ghodsypour & O'Brien 1998: Verma & Pullman 1998; Ittner at al. 1999; Stoddard & Fern 1999; Lamming *et al.* 2000: Petroni and Braglia 2000; Swift & Gruben 2000; Kotabe & Murray 2001; Tracey & Tan 2001; Bhutta & Huq 2002; Kannan & Tan 2003, Shahadat 2003).

The different literatures were reviewed related to vendor selections which, were published in different refereed academic journals, which are listed below.

- ✓ International Journal of Electronics Business
- ✓ Industrial Marketing Management
- ✓ Emerald-International journal of Bank Marketing
- ✓ Technological and Economic Development of Economy
- ✓ International Journal of Purchasing & Materials Management
- ✓ Supply Chain Management
- ✓ Emerald-Industrial Management & Data Systems
- ✓ Expert Systems with Applications
- ✓ Journal of International Business Studies
- ✓ International Journal of Physical Distribution & Logistics Management
- ✓ Journal of International Business studies
- ✓ Purchasing
- ✓ International Journal of Operations and Production Management
- ✓ Journal of Business Research
- ✓ Journal of Information Technology
- ✓ European Journal of Purchasing & Supply Management
- ✓ Journal of Operations Management and
- ✓ Journal of Purchasing and Supply Management.
- ✓ Science Direct
- ✓ NESLI
- ✓ Proquest (ABI/INFORM)
- ✓ Ingenta
- ✓ Blackwell
- ✓ Wiley Science
- ✓ Emerald
- ✓ USTOR
- ✓ Web of Science
- ✓ Swetsnet
- ✓ EBSCO
- ✓ Inderscience

The review was done keeping the three primary objectives in mind; (1) to understand the existing research in vendor selection, especially in IT related to banking & financial sectors since most of the banks are heavily dependent of IT and technology vendor, and are entering into a long-term relationship (Npower, 2006, Forrester, 2011), (2) to understand the various criteria and sub criteria which have been assessed by earlier researcher and (3) to understand the different methodologies have been researched over the years to evaluate the right vendor. The researcher has used tabular format wherever possible for the ease of understanding for the readers.

There are several articles were reviewed that focused on international vendor selection. Outsourcing has opened up the opportunities in terms of lower production and labour costs that other countries can offer. Then, it becomes necessary to understand and analyse these countries' political, legal, economic, socio-cultural and technological features as well as how to go about doing business in these countries. The selection of vendors in foreign countries may then become complicated due to the uncertainties caused by lack of information and/or risks (such as safety and security related) associated with these countries' business environment. It was observed from the review that the papers reporting the various aspects of vendor selection process in a particular country is limited to mainly developed (technologically advanced) countries. The USA is the most widely studied country. Other countries included Canada (Bowman *et al.* 2000), Germany (Bowman *et al.* 2000; Buskens *et al.* 2003) The Netherlands (Buskens *et al* 2003), Switzerland (Quayle 2002), Sweden (Olhager & Selldin 2004), China (Choy *et al.* 2005; Kaynak 1989; Murray *et al.* 2005; Qu & Brocklehurst 2003), Japan (Dyer & Chu 2000; Iskander *et al.* 2001) and Korea (Dyer & Chu 2000, Park & Krishnan 2001).

2.3 Literature review on decision criteria

The articles are initially categorised based on keywords under two broad groups: decision criteria used; decision making methods and tools

The first broad category includes the papers on vendor selection (decision) criteria that examine several issues. The most common issue is how to find industry specific criteria and assign weights to the each criterion. Once the criteria are identified, and then is the categorisation of decision criteria, which is in general into three broad areas: critical, objective, and subjective criteria (Houshyar *et al* 1992). A few papers addressed the use or preferences towards different set of decision criteria by individual buyers' demographic differences. Decision criteria used for vendor selection can be different depending on the size of the buyer organisation. Large companies use a different set of criteria and a formal approach when selecting vendors compared to small and medium sized enterprises (Pearson and Ellram 1995). In order to understand about different criteria that have been studied in different countries and in different industries, the researcher has reviewed different articles, literatures etc, which have been listed in tabular format as in table 2.1, which listed the top criteria discussed by different authors based on different industry and different geography. The objective of this is to consolidate all the top criteria which was discussed by different researcher over last few decades and later on find the relevance of these criteria on this research matter i.e. technology vendor selection.

Table 2.1 Study on vendor selection criteria

Authors	*Industry*	*Regions*	*Vendor selection criteria (top 6)*
NPower, 2011	High technology	USA	Assess feasibility Gather requirements Research & refine options Evaluate vendors Select & engage vendor to manage implementation
Gartner Industry research, 2011	Core banking	USA	Functionality Flexibility Cost Viability Operational performance Program management
Ramune Kugyte, Laimona Šliburyte, 2005	Hi-Technology Financial services	Europe	Pricing, Inconvenience, Core service failure, Service encounter failure Response to service failure Ethical problems
Bharadwaj (2004)	Electronic components	Multiple regions	Product quality Conditions of products on arrival On-time delivery performance Accuracy in filling orders Order cycle time Ability to fill emergency orders Price
Kannan & Tan (2003)	General	US & Europe	Ability to meet delivery due dates Commitment to quality Technical expertise Price of materials Frequent communications Respond to unexpected demand
Gerrard, Cunningham (2001)	Consumer banking	Singapore	Secure feeling; Electronic services; Services provision

Hirakubo & Kublin (1998)	Electronic & office equipments	Japan	Price Delivery Quality Capability Technical Manufacturing
Mummalaneni et al. (1996)	General	China	Quality On-time delivery Responsiveness to customer needs Price/cost Quality of relationship with vendor Professionalism of salesperson
Haron, Ahmad, Planisek, 1994	Consumer banking	Malaysia	Fast and efficient services; Speed of transactions; Friendliness of bank personnel. Reputation and image of bank
Billesbach *et al.* (1991)	JIT companies	Multiple regions	Delivery reliability Quality conformance Response flexibility Price Technical support JIT capability

The purchasing processes of vendor throughout the history have been selected according to the criteria. The most common criteria ever used in vendor selection are mentioned by (Dickson, 1966), he ranked a number of various criteria taking the relative importance of each criterion into consideration. Overall 23 criteria were presented by Dickson as shown in table 2.2, still cover the majority of the criteria presented in the literature until today. The evolution of technological importance modified the degrees of the relative importance of these criteria.

Table 2.2 Dickson's vendor selection criteria & rank

Rank	***Factor***	***Mean Rating***	
1	Quality	3.508	Extreme importance
2	Delivery	3.417	
3	Performance history	2.998	
4	Warranties & claim policies	2.849	
5	Production facility & capacity	2.775	Considerable importance
6	Price	2.758	
7	Technical capability	2.545	
8	Financial position	2.514	
9	Procedural compliance	2.448	
10	Communication system	2.426	
11	Reputation & position in the industry	2.412	
12	Desire for business	2.256	
13	Management & organisation	2.216	
14	Operating controls	2.211	Average importance
15	Repair service	2.187	
16	Attitude	2.120	
17	Impression	2.054	
18	Packaging ability	2.009	
19	Labour relation record	2.003	
20	Geographical location	1.872	
21	Amount of past business	1.597	
22	Training aids	1.537	
23	Reciprocal arrangements	0.610	Slight importance

Most papers attempted to identify and determine the relative importance of criteria for vendor selection in various industries; more reviews have been done by the researcher to understand the different criteria were studied for vendor selection in different industries; these are listed in table 2.3. This has helped the researcher to identify different criteria and sub criteria which can be considered for vendor selection in this research.

Table 2.3 List and summary of papers related to selection criteria

Paper ID	Brief description of content
Svensson (2004)	Investigates the models of supplier segmentation and supplier selection criteria.
Sharland, Eltantawy & Giunipero, (2003)	Examines the impact of cycle time on supplier selection
Humphreys, McIvor & Chan (2003)	Attempts to integrate environmental factors into the supplier selection process
Humphreys, Wong & Chan (2003)	Develops a decision support tool which should help companies to integrate environmental criteria into their supplier selection process
Yan & Wei (2002)	Uses supplier selection criteria as an example to apply a proposed compromise weighting in a group decision making environment.
Krause, Pagell & Curkovic (2001)	Aims to develop a set of measures of purchasing's competitive priorities
Akarte, Surendra, Ravi & Rangaraj (2001)	Identifies 18 criteria and groups them into four categories
Swift and Gruben, (2000)	Examines the differences between the weightings applied to supplier selection criteria by male and female purchasing managers
Avery (2000)	Presents the experiences of three purchasing professionals and their preferred criteria when purchasing IT and identifies the criteria used for IT purchases
Bowman, Farleyn & Schmittlein (2000)	Examines the relative importance of factors that affect supplier selection and level of usage for global business services providers
Verma & Pullman (1998)	Examines the differences in weights assigned to decision criteria in actual choice of suppliers and perceived importance of decision criteria before selecting the suppliers
Craig, Daugherty & Ellinger (1997)	Aims at exploring the criteria used during the selection of systems/software vendors for all or part of an integrated logistics information system.
Lambert, Adams & Emmelhainz (1997)	Examines the decision criteria used by healthcare organisations and looks at the weights assigned to them
Min & Galle (1997)	Draws attention to include environmental criteria in the supplier selection process.

Table 2.2 continued.

Paper ID	Brief description of content
Choi & Hartley (1996)	Aims to identify supplier selection practices based on a firm's position on supply chain and to provide recent supplier selection practices that incorporate contemporary supplier management issues.
Patton (1996)	Attempts to find out what criteria and which methods purchasing professionals use in practice.
Swift (1995)	Aims to determine whether there are differences in supplier selection criteria between purchasing managers who have a preference for single sourcing and those who prefer multiple sourcing.
Thorelli & Glowacka (1995)	Reports on factors thought to have an impact on decisions of purchasing professionals to source internationally.
Pearson & Ellram (1995)	Examines and explores the differences in decision criteria used for supplier selection in small and large organisations.
Wilson (1994)	Compares the relative importance of supplier selection criteria of late seventies and eighties with those of nineties.
Shipley, Egan & Edgett (1991)	Compares the performance of two channel designs in meeting customer sourcing criteria for industrial re-buy products.
Weber, Current & Benton (1991)	Looks at the criteria and analytical methods used in the vendor selection process.

The decision criteria used for vendor selection and the weight assigned to them are different due to a number of factors as described below;

- The demographic characteristics of the purchasing managers (Hirakubo and Kublin 1998, Kannan and Bakker, 2004, Mummaleneni *et al.* 1996, Patton 1996, Pearson and Ellaram 1995, Swift and Gruben 2000, Verma and Pullman 1998, Weber *et al.* 1991, Wilson 1994, Yan and Wei 2002),
- The size of the buyer organisation (i.e. small vs. large) (Pearson, Ellaram 1995), the preferred sourcing strategy (i.e. single vs. multiple).
- The type of products and/or services purchased (Abratt 1986, Akarte *et al.* 2001, Avery 2000, Bowman *et al.* 2000, Craig *et al.* 1997, Deng & Wortzel 1995, Gonzalez *et al.* 2004, Kannan and K C Tan 2002, Katsikeas *et al.* 2004, Lambert *et al.* 1997, Sharland *et al.* 2003, Shilpey *et al.* 1991, Svensson 2004).

- Some scholars emphasised the need for integrating environmental criteria into the vendor selection process as more and more end users (customers) become aware and concerned about the environmental issues (Humphreys et al. 2003, Min and Galle 1997, Noci 1997). However, environment seems more related to discrete manufacturing industry.

The findings of the previous researches indicate that while price, quality, delivery reliability and service are typical determinants of vendor selection, the specific criteria used and their relative importance are highly dependent on the type of product, the type of purchase being made and circumstances surrounding the decision to engage a vendor. As it was found from the literature survey that price to cost though important to select a vendor but is not a deciding factor to select IT vendor. A long term return on investment is a strategic decision in regard to select IT vendor. Quality deliverables, technical offer, service, business process understanding etc are important to select technology vendor. However, more reviews have been done to know the various methodological approach and the complexities of vendor selection. The discussions about different methodology are exemplified in the following section.

2.4 Vendor selection methodologies

A number of papers reported the use of mathematical programming methods such as goal programming, integer goal programming, total cost based approach and data envelopment analysis. There are also some papers on the use of artificial intelligence and expert systems, which included the techniques such as case, based reasoning and knowledge based systems supported by computer software. A fresh approach for effective vendor selection processes in electronic marketplaces was introduced by Chamodrakas *et al.* (2010). It comprises of an evaluation method in two stages: initial screening of the vendor through the enforcement of hard constraints on the selection criteria and final vendor evaluation through the application of a modified variant of the Fuzzy Preference Programming (FPP) method.

Chan *et al.* (2007) implemented a fuzzy extended method using critical decision criteria to determine critical factors such as the risk factors, cost, quality, service performance for selecting efficient global supplier in present business scenario. Chin *et al.* (2011) used ANP and TOPSIS to calculate weight of criteria and rank of the vendors. Pooniyamoorthy *et al.* (2011), proposed a composite model of structural equation modeling and fuzzy AHP. Yuh-jen (2011), utilized SWOT to identify company's competitive strategy. DEA is then applied to screen potential vendors, after which TOPSIS is used to rank the vendors. Saman *et al.* (2011) applied quantified SWOT in context of vendor selection, since SWOT analysis is one of the most well known strategic decision making technique. Chamodrakas *et al.* (2010), employed for initial screening of vendors and AHP is employed for the final selection. Amy (2009) had applied fuzzy AHP for vendor selection. Demirtas *et al.* (2008), applied ANP – multi-objective programming. Ismail *et al.* (2003) proposed a methodology for selecting alternatives from a finite set with multiple, conflicting objectives, both qualitative and quantitative in nature. William *et al.* (2010) in their review paper concluded that individual approaches were slightly more popular than integrated approaches; DEA is employed frequently for its ability to handle both qualitative and quantitative data. As for the integrated approaches, integrated AHP approaches are fairly popular for their simplicity and ease of use. Tseng *et al.* (2009), proposed a structure for vendor selection, considering various conflicting criteria, which facilitates in selecting suitable vendors from finite alternative set.

The Analytical Hierarchy Process (AHP), Multiple Attribute Utility Theory (MAUT), Outranking methods are well known and typical multiple criteria decision making methods suggested for vendor selection as Patton (1996) claimed there is still not much evidence which methods are actually used by individual buyers. The use of multivariate statistical analysis such as Structural Equation Modeling, principal component analysis and factor analysis for vendor selection practice has also been reported in the literature. More than half of the papers reviewed reported and/or introduced the use of different selection making methods and tools for vendor selection.

The methods reported for vendor selection can be clustered into several broad categories: traditional (conventional) multiple criteria decision making (MCDM) techniques, mathematical programming, artificial intelligence and expert systems, and multivariate statistical analysis. In addition, there are two more categories that are somewhat different from the categories mentioned earlier: group decision-making and multiple methods. Some the available models reviewed from journals & literatures on vendor selection pertaining to IT outsourcing are listed in table 2.4.

Table 2.4 Vendor selection methodologies

Methodology	***Authors***
Multi-criteria decision making approaches	Ho *et al.* (2010)
Satisficing and fuzzy AHP.	Chamodrakas *et al.* (2010)
Mixed Integer Programming	Weber and Current (1993)
A hybrid MCDM model	Shyur, & Shih (2006)
Analytical Hierarchy Process	Barbarosoglu and Yazgac (1997)
Analytical Network Process	Sarkis and Talluri (2002)
Multi-criteria decision aid method	Teixeira (2007), Dulmin & Mininno (2003),
Decision support system	Valluri & Croson (2005)
Total Cost of Ownership	Degraeve *et al*, (2004)
Human Judgment Models	Patton (1996)
Principal Component Analysis	Petroni and Braglia (2000)
Neural Networks	Siying *et al.* (1997)
Data Envelopment Analysis	Narasimhan *et al.* (2001), Weber and Desai (1996), Weber *et al.* (1998)
Interpretive Structural Modeling	Mandal and Deshmukh (1994)
Game Models	Talluri (2002), Talluri and Narasimhan (2003)
Statistical Analysis	Mummalaneni et al. (1996)
Discreet Choice Analysis Experiments	Verma and Pullman (1998)

Many models and methods have been developed to solve the problem of vendor selection by different researchers. Each method takes different criteria into consideration the Matrix method, Analytical Hierarchy Process (AHP), Data Envelopment Analysis (DEA), Structural Equation Modeling (SEM), Analytic network process (ANP) are a few methods to name. The researcher has done further study and found that there are various methods have been adopted by different researcher to establish those models.

Weber *et al.* (1991) indicated that the most utilised approach has been linear weighting models. It assigns a weight to each criterion and calculates the total score for each vendor by summing up the vendor's performance on the criteria multiplied by these weights. Mathematical programming models often consider only the more quantitative criteria; this approach includes the Principal Component Analysis (PCA) and the Artificial Neural Network (ANN). According to Bello (2003), the PCA method has two advantages that are accessible and capable of handling multiple conflicting criteria. The ANN model saves money and time. The weakness of this model is that it demands specialised software and requires qualified personnel who are expert on this subject. The table 2.5 illustrates the list and classification of vendor selection methods reported on the reviewed articles; under the category the researcher has briefed the different models have been studied in the relevant literatures.

Table 2.5 List and classification of vendor selection methods

Category	Method	Paper Reference number
Artificial Intelligence & Expert Systems	Neural networks	Choy *et al.* (2003,2004)
	Case-based reasoning	Choy *et al.* (2002, 2003, 2004, 2005), Humpherys *et al.* (2003)
	Bayesian Belief Networks	Kreng & Chang (2003)
Mathematical programming	Total cost based approaches	Atkinson (2004); Bahli & Rivard (2003); Berger & Zeng (2006); Bhutta & Huq (2002); Degraeve *et al.* (1998, 1999, 2000, 2004, 2005); Peng & York (2001); Qu & Brocklehurst (2003); Roodhooft & Konnings (1996), Smytka & Clemens (1993)
	Non-linear programming	Ghodyspour & O'Brien (2001)
	Mixed integer programming	Chakravastia *et al.* (2002); Degraeve *et al.* (1999), Jayaraman *et al.* (1999)
Mathematical programming	Linear programming	Ghodyspour & O'Brien (1998, 2001); Yan & Wei (2002)
	Integer programming	Feng *et al.* (2001); Gupta & Krishna (1999)
Mathematical programming	Heuristics	Akinc (1993); Basnet & Leung (2005); Ganeshan *et al.* (1999); Tempelmeier (2002).
	Goal programming	Dowlatshahi (2001); Karpak (1999); Wang *et al.* (2004)
	DEA	Braglia & Petroni (2000); Liu *et al.* (2000), Weber (1996); Weber *et al.* (1998, 2000)
MCDM	AHP	Akarte *et al.* (2001); Barbarosoglu and Yazgac (1997), Bhutta & Huq (2002); Ghodyspour & O'Brien (2001); Muralidharan *et al.* (2001; Nydick & Hill (1992); Sarkis & Talluri (2002); Tam *et al.* (2001); Wang *et al.* (2004); Yahya & Kingsman (1999).
	Outranking methods	Dulmin & Mininno (2003).
	MAUT	Fonseca *et al.* (2004); Min (1994).
	Linear weighted point	Muralidharan *et al* (2001)

Table 2.5 continued.

Category	Method	Paper Reference number
	Judgmental modeling	Naude & Lockett (1993); Da Silva *et al.* (2002)
	Interpretive Structural Modeling	Mandal & Deshmukh (1994)
	Categorical method	Houshyar &Lyth (1992)
	Fuzzy sets	Wu (1990)
	Structural equation modeling	Tracey & Tan (2001), Lin *et al.* (2005)
Multivariate statistical analysis	Principal component analysis	Petroni & Braglia (2000)
	Factor Analysis	Tracey & Tan (2004); Krause *et al.* (2001)
	Confidence interval approach	Muralidharan *et al.* (2001)
Other decision making tools	Group decision making	Yan & Wei (2002); Tam *et al.* (2001); Patton (1997); Muralidharan *et al* (2001, 2002); Mandal & Deshmukh (1994); Han & Ahn (2005).
	Multiple Methods	Akinc (1993); Bhutta & Huq (2002); Degraeve *et al.* (2005); Ghodyspour & O'Brien(1998); Muralidharan *et al* (2001); Wang et al. (2004); Weber *et al.* (1998, 2000)

Over the years, researchers have begun to classify and group the individual vendor selection methods into a number of broader categories, with each classification having both advantages and disadvantages. The Multiple Attribute Utility Theory (MAUT) method has the advantage that it enables purchasing professionals to formulate viable sourcing strategies and is capable of handling multiple conflicting criteria. However, this method is only used for international vendor selection, where the environment is more complicated and risky (Bross and Zhao, 2004).

Chen et al. (2007) had applied Fuzzy logic approach measures for vendor evaluation. This approach can help decision making to find out the appropriate ordering from each vendor. A review of the vendor selection literature shows that the AHP method is one of the most commonly applied methods in practice. AHP is an ideal method for ranking alternatives when multiple criteria and sub-criteria are present in the selection process. AHP was introduced by Saaty, (1980). The use of AHP is increasing with time; since a lot of journals are bringing out special issues, on this topic. Omkarprasad, and Sushil (2006).

In order to understand the principles and concept of SEM, the researcher has studied through the "Introduction of Structural Equation Modeling using AMOS (Academic Computing and Instructional Technology Services UT-Austin); AMOS is a (Analysis of Moment Structures) software. Structural equation modeling (SEM) encompasses diverse statistical techniques as path analysis, confirmatory factor analysis, causal modeling with latent variables, and even analysis of variance and multiple linear regressions. This study has helped the researcher to develop the SEM model using AMOS.

Before outlining the final conclusion on the literature review, the researcher had done more literature review based on different methods which have been followed by researchers since 1968 till 2011. This has been listed in the table 2.6 in descending order from 2011 to 1968. As it has been recongnised that relevant criteria are very important for the data collection and to establish the model, the review was done on the last >40 years literatures, journals etc are available to understand the different selection process pertaining to different industries that have been researched and different criteria have been taken into consideration.

Table 2.6 Literature review on vendor selection methods

Authors, year of publication	**Title**	**Key words for the criteria used by Dickson**	**Technique/Methods**
Tanmoy, Tamal, Pranab (2011)	"Application of analytic hierarchy process and heuristic algorithm in Solving vendor selection problem"	Quality, delivery price.	Analytical Hierarchy Process
Parthiban *et al* (2011)	A Model for Supplier Selection using Analytic Network Process	Benefits, Opportunities, Costs and Risks	ANP
Vinodh *et al*. (2011)	Application of fuzzy analytic network process for supplier selection in a manufacturing organisation	Net price	Expert Systems with Applications
Chin & Chi Bien (2011)	An ERP model for supplier selection in electronic industry	Quality, delivery, performance history, net price.	Expert systems with application

Table 2.6 continued

Authors, year of publication	**Title**	**Key words for the criteria used by Dickson**	**Technique/Methods**
Keith *et al* (2011)	Competitive Potential of Micro-sized IT Outsourcing Vendors	Delivery, quality, net price, repair service, technical capability, performance history, production facilities and capacity, training aids, operational controls, reputation and position in industry, financial position, attitude, communication systems, bidding procedural compliance, management and organisation, packaging capability, labour relation record, geographical locations.	SEM
Ameer *et al* (2010)	Vendor selection using fuzzy integration	Quality, delivery, net price, management and organisation.	Fuzzy AHP
Jitendra & Nirjhar (2010)	"A Hybrid method for vendor selection using Neural Network"	Quality, delivery, cost.	AHP
Rong-Ho Lin (2009)	An integrated FANP–MOLP for supplier evaluation and order allocation	Net price, delivery, quality, reputation and position in industry, past business.	Applied mathematical modeling

Table 2.6 continued.

Authors, year of publication	**Title**	**Key words for the criteria used by Dickson**	**Technique/Methods**
Min & Liu (2010)	The supplier selection application based on two methods	Management & organisation	VIKOR algorithm with entropy method and Fuzzy TOPSIS with vague sets method
Li *et al.* (2007)	A grey based decision-making approach to the supplier selection Problem	Quality, delivery, net price	Mathematical & computer modeling
You & Hongli, (2007).	Information system outsourcing vendor selection	Quality, delivery, production facilities and capacity, net price.	Analytical hierarchical process.
Hu & Bentler, (1999).	Cutoff criteria for fit indexes in covariance structure Analysis: Conventional criteria versus new alternatives.	Net price	SEM
Sharma, Benton and Srivastava (1989)	Competitive strategy and purchasing decision.	Net price, quality, delivery	Non-linear goal performing model.
Pan (1989)	Allocation of order quantity among suppliers	Net price, quality, delivery	Single objective linear programming model.
Bernard (1989)	Managing vendor performance.	Quality, delivery, net price, management & organisation, service.	Conceptual.
Chapman (1989)	Just-in-time supplier inventory: An empirical implementation model	Quality, delivery, production facilities and capacity	Empirical

Table 2.6 continued.

Authors, year of publication	Title	Key words for the criteria used by Dickson	Technique/Methods
Ronen and Trietsch (1988)	A decision support system for purchasing management of large projects	Delivery, net price	Stochastic, stationary inventory model.
Ansari (1988)	"JIT purchasing as a quality and production centre"	Quality, delivery, net prices, geographical location, attitude, packaging.	Conceptual
Burton (1988)	Repetitive sourcing strategies: "Tying the knot with your supplier".	Quality, delivery, production facilities and capacity, net price, technical capability, packaging ability, geographic location, training aids, management & organisation, operational controls.	Conceptual
Chakravarty & Martin (1988)	An optimal joint buyer-seller discount pricing model.	Net price	EOQ
Newman (1988)	Insuring quality: Purchasing's role	Quality	Statistical process control
Newman (1988)	The buyer-supplier relationship under just-in-time	Quality, delivery, production facilities and capacity, net price, technical capability, packaging ability, geographical location	Conceptual
Turner (1988)	An independent system for the evaluation contract tenders.	Net price, production facilities and capacity.	Mixed integer optimisation model.
Soukup (1987)	Supplier selection strategies	Production facilities and capacity, net price, technical capability, financial position, desire for business; management and organisation, attitude, geo- graphical location	Linear weighting model using probabilities.

Table 2.6 continued.

Authors, year of publication	Title	Key words for the criteria used by Dickson	Technique/Methods
Gregory (1986)	Source selection- A matrix approach	quality, delivery, performance history, production facilities and capacity, net price, technical capability, bidding procedural compliance, reputation and position in industry, management and organisation, geographical location.	Sourcing worksheet with linear weighting model.
Hahn, Kim and Kim (1986)	"Costs of competition: Implications for purchasing strategy",	Quality, delivery, production facilities and capability, net price, technical capability, geographical location, commodity purchasing.	Linear & dynamic programming models conceptualised discussed.
Narasimhan and Stoynoff (1986)	Optimising aggregate procurement allocation decisions	Production facilities and capacity, net price	Mixed integer optimization programming model.
Timmerman (1986)	An approach to vendor performance evaluation	Quality, delivery, performance history, price, technical capability.	Linear weighting model
Bender, Brown, Isaac and Shapiro (1985)	Improving purchasing productivity at IBM with a normative decision support system- IBM for wide range of commodities.	Quality, delivery, production facilities and capacity, net price.	Mixed integer optimisation programming model as part of a decision support system.

Table 2.6 continued.

Authors, year of publication	**Title**	**Key words for the criteria used by Dickson**	**Technique/Methods**
Mazurak, Rao and Scotton (1985)	Spreadsheet software applications in purchasing.	Quality, delivery, net price, financial position.	Spreadsheet vendor evaluation system using linear weighting model.
McFillen, Reck and Benton (1983).	An experiment in purchasing negotiation.	Price, quality, delivery, service.	An empirical study.
Browning, Zabriskie and Huellmantel (1983)	Strategic purchasing planning.	Delivery, net price, technical capability, production facilities and capacity	Conceptual
Kraljic (1983)	Purchasing must become supply management.	Quality, delivery, production facilities and capacity, technical capability.	Conceptual
Monczka, Giunipero and Reck (1981)	Perceived importance of supplier information.	Quality, delivery, performance history, production facilities and capacity, net price, financial position, reputation and position in industry, management and organisation, labor relations record, geographical location.	Empirical
Crocell (1980)	Measuring purchasing effectiveness.	Quality, delivery, net price	Conceptual
Roberts (1978)	A vendor delivery rating model	Delivery	Linear weighting model for delivery performance
Anthony and Buffa (1977)	Strategic purchasing scheduling- General industrial purchasing.	Delivery, net price.	Linear programming model based on transportation model.

Table 2.6 continued.

Authors, year of publication	Title	Key words for the criteria used by Dickson	Technique/Methods
Wieters (1976)	Influences on the design and use of vendor performance rating system	Production facilities and capacity, technical capability, financial position, reputation and position in industry, management and organisation, operational controls, repair service, geographical location.	Empirical
Lamberson, Diederich and Wuori (1976).	Quantitative vendor evaluation	Quality, delivery, performance history, production facilities and capacity, net price, technical capability, financial position, management and organisation.	Decision analysis worksheet with linear Weighting model.
Payne (1970)	Development of a supplier evaluation technique utilising financial information.	Financial position	Empirical
Wind and Robinson (1968)	The determinants of vendor selection: The evaluation function approach	quality, delivery, net price, reputation and position in industry, geographical location, reciprocal arrangements, performance history, technical capability, communication system	Generalised linear weighting model.

The full citations of the above table are provided at the end of the article in the reference section.

2.5 Issues & challenges of vendor selection

In the past two decades many organisations have turned to other organisations to satisfy their information systems needs (Ramy *et al* 2011). IT vendor selection and outsourcing is as an act of delegating or transferring some or all of the IT related decision making rights, business processes, internal activities, and services to external providers, who develop, manage, and administer these activities in accordance with agreed upon deliverables, performance standards and outputs, as set forth in the contractual agreement (Subshankar, Bindu, 2008). Dibbern *et al.* (2004) argued that outsourcing and vendor selection is a practitioner driven phenomenon and numerous risks lie in the selection of appropriate vendors. In information technology (IT) vendor selection, various vendors may be asked to bid to provide IT services, with or without the use of intermediaries who can help in the process of vendor selection (Agrawal *et al.*, 2005). One danger is the often large disparity between what vendors initially advertise in their proposals and what is delivered at the end of the day.

A problem that is frequently noted is that the exact value and service requirements cannot be clearly determined. Vendors often have to bid based on incomplete information, as the overall IT environment of an organisation is often too highly integrated to evaluate objectively the actual service costs and technical requirements. The value often lies in the cross-functional integration of business processes and the penetration of IT into the core of organisational functions. These values are difficult to measure and contract for. The difficulty in bidding circumstances is to select those vendors that offer the best deal, and here the focus tends to be on what cost efficiencies vendors can deliver (Kern *et al.*, 2002). The likely danger is that vendor's can out-bid and subsequently find it impossible to continue with the deal as priced and structured. These experiences can place considerable pressure on vendor selection or on the outsourcing venture and the relationship to the point where re-negotiation or early termination becomes the only option.

Therefore, significant costs will arise for both parties, raising general doubts over the financial viability of such deals in general. Understanding how such scenarios can evolve is the starting point for avoiding these situations. Thus, related challenges for managers are then to select an appropriate vendor who has expertise in assessing the scope of the project as well as the vision to foresee the scenarios that may arise. According to Aron *et al.* (2005) vendor selection or outsourcing ventures are also exposed to operational risks caused by the breakdown in operations at the vendor locations. These risks are not caused by deliberate actions by the vendor or by unethical behavior of the vendor. Rather, they are a byproduct of the complexity of operations, the geographic separation between client and vendor, the cultural gap between the environments of the client and the vendor, and/or the limitations of the communications and transmission systems between the two.

Vendor selection at a different geography and offshore outsourcing introduces many other risks that need consideration before a vendor is selected. Evaristo *et al.*, (2005); and Kliem, (2004) have explored some of these risks as discussed below:

Cost Savings Risk: Lower wages in developing countries do not necessarily translate to overall cost savings. The provision of poor estimates, provider's failure to deliver, and poor selection of provider are some of the causes. The type of communication, long distance management, travels, training, and provider management costs must also be factored into the analysis.

Internal Employee Issues: A backlash among the enterprise's current employees is to be expected, as an operation is offshore since their jobs are at stake.

Management Complexity: Management is inherently difficult in the complexity of the off shoring process with multiple development centers in different time zones, continents, and cultures.

Geopolitical Risk: Political instability, labor unrest, power shortage, and infrastructure status may affect the software development progress.

Risk of Intellectual Property (IP) Loss: The enterprise's IP may get stolen in outsourcing and subcontracting, resulting in a provider one day becoming a competitor. Some countries have rather lax laws on IP protection while other countries may have laws on software piracy and data privacy but that are seldom enforced.

International Data Sharing: When data from different global locations are accessed and consolidated, it requires well-defined and highly compatible global data standards. Furthermore, issues may arise due to negligent or primitive legal systems regarding data sharing.

Global Cultural Environment: Cultural differences exist with differences in language, customs and even the pace of daily life. Language problems in international collaboration, cultural differences in employer-employee relationships, seniority and personal relationships with authority, and socialist/capitalist principles cannot be ignored.

Financial Risks: Currency exchange rate fluctuations are important and cannot be wished away.

Difficulties in Communication and Coordination: Poor telecommunications infrastructure in underdeveloped countries can be a serious drawback.

These risks lead to the primary challenge of selecting an appropriate vendor in an appropriate country who will have expertise in outsourcing, including the ability to foresee and deal with various scenarios and problems that may occur, expertise in the field, ability to maintain expertise and provide services, and cultural and organisational fit.

2.6 Summary of literature review

The researcher had done extensive literature review; the review consists of literature published from 1966, with the selection criteria defined by Dickson to till 2011; the literature review aimed to explore the various issues affecting the vendor selection process. The various criteria and sub-criteria for this research have been listed from the literature review, which are relevant to technology vendor selection. This has been discussed detail in next chapter.

Moreover from the literature review, it was revealed that there is no research available involving SEM and AHP approach to select technology vendor. Thus the model proposed by the researcher is distinctive in nature.

The wide ranging literature review suggests that much of the focus within vendor selection processes has been given to the selection criteria and the selection methods used. The review exposed the areas that attracted little or no research attention. With the developments in the world economy (i.e. globalisation) and in communication, information technology, there is a tendency towards exploring the issues and concerns over international vendor selection as well as a tendency towards better understanding of buyer-seller relationships. Another tendency in vendor selection studies is to look at the effects of selecting and assessing vendors online (i.e. e-commerce, e-procurement).

The literature review revealed some trends in vendor selection related studies. Specifically, the review revealed that greater emphasise was placed on (i) decision criteria and associated weightings used for vendor selection and (ii) decision making methods/tools used and/or proposed for vendor selection.

This research has been achieved through variety of progresses and different steps which have been discussed in the following chapters.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Overview

This chapter addresses the identification of criteria and sub criteria, which is an important phase of this research. SEM and AHP are introduced through the conceptual model for vendor selection, wherein all the steps that have been followed to achieve research objectives are discussed in this chapter. The research hypothesis is discussed in this chapter.

3.2 Introduction

A composite model for measuring vendor selection was developed in the research. Composite means the structure or entity is made up of distinct components. The researcher has applied distinct techniques like SEM and AHP to develop the model. The model is based on four steps as below:

Step1: Select supplier selection criteria

There are different specific requirements for vendor selection in different industries (Liu and Hai, 2005). In this research the vendor selection criteria are chosen based literature on the relevant field of work and through the discussions with the professionals in the related field. The criteria were then detailed into sub-criteria, wherein each criterion is dependent on one or several sub-criteria.

Step2: Determine the comparison matrices

A questionnaire was developed to understand the relevance and significance of each criterion and sub criteria.

Step3: Calculate the weights of criteria

Once all priorities among criteria and sub-criteria are obtained, the weights of each criterion are found out by using SEM

Step4: Calculate the weights of vendors

The relative weightage of the vendors with respect to each criterion are found out by using pair wise comparison technique of AHP approach.

3.3 Criteria and sub criteria for vendor selection

The first step in any vendor rating & selection procedure is to establish the criteria to be used for assessing the vendor. Most vendor selection problems essentially entail more than one criterion (Navid & Yusuff, 2009). Therefore Multiple Criteria Decision Making (MCDM) techniques have been used to help decision experts in making their selection. Unlike what have been done in most of the former studies, criteria for evaluating the alternatives are not always independent, determining interdependencies among vendor selection criteria but often interact with each other.

The literature review had offered an overview of the vendor selection methods in different industry; the discussions with various experts and professional had helped the researcher to understand the real life complexity in vendor selection process especially in BFSI. Dickson's (1966) study was also considered as initial guideline to select criteria in this research which are listed as below. The criteria are underlined as in below, were taken from Dickson's research.

1) The net price offered by each vendor.
2) The ability of each vendor to meet quality specification consistently.
3) The service likely to be given by each vendor.
4) The ability of each vendor to meet the specified delivery schedule.
5) The geographical location.
6) The financial position and credit rating of each vendor.
7) The software development facility and capacity of each vendor.
8) The amount of past business that has been done by each vendor.
9) The technical capability (including research & development) of each vendor.
10) The management & organisation of each vendor.
11) The communication system (with information on progress) of each vendor.
12) The position in the industry (including reputation) of each vendor.
13) The attitude of each vendor towards the buyer organisation.
14) The desire of business shown by each vendor.
15) The warranties and claim policies of each vendor.
16) Compliance with buyer's procedure.
17) The performance history of each vendor.

Studying related articles to vendor selection such as Tam & Tummala (2001), Handfield *et al.* (2002); Zhang, Lei, Cao and Ng (2003); Bello (2003); Yu and Jing (2004); Liu and Hai (2005); Amid *et al.* (2006); Przewosnik *et al.* (2006) and Chen-Tung *et al.* (2007), Jiann *et al* (2008), Navid *et al* (2009), Keith *et al* (2011), using expertise of experts and from researcher's own professional experience the key and crucial 13 criteria have been identified. These are namely vendor credibility, management and organisation, technical elements, product stability or durability, processes, quality, financial/commercial position, vendor culture, geographical presence, services/support, cost, relationship, co-operation, safety and environment concern. These are often discussed in various journals in the field of management as well as in the banking application and IT.

Moreover, the researcher also referred to other sources like text books in mobile banking, quality management, websites and academic studies conducted in the related areas within the literature study and identified 150 sub criteria as the basis of this research.

In order to identify the most important criteria and sub-criteria related to mobile banking services, further refinements were carried out. The researcher met directly with professionals in different banks and information technology services companies who are servicing BFSI, well experienced teaching experts and research experts frequently, with prior appointments. In their detail and in-depth discussions, 3 criteria and 97 sub criteria were indentified and omitted, because of repeated or super imposed sub criteria and also, based on the importance and relevance of criteria and sub criteria through their knowledge, experience and relevant to the industry and technical application; with regards to this point that considering all the criteria and sub-criteria for vendor selection is impossible, the main and important criteria have been extracted by expert judgments, which are listed in table 3.1. The evaluation and determination of weight of each vendor have been done in this research based on these identified criteria.

Table 3.1 Criteria & sub criteria for vendor selection

Criteria	***Sub -criteria***
1. Vendor credibility->VCB	(1)Reputation in the market, (2) Reference clients, (3)Strategic directions, (4)Existing relationships (5)Trustworthiness (6)Technical project management
2. Management and organisation -> MNO	(7) Physical size & Geographical presence, (8) Ethical standards, (9) Conflict management ability, (10) Account management, (11) Employees (educational qualifications of human resources)

Table 3.1 continued

Criteria	*Sub -criteria*
3. Technical elements-> TCB	(12) Usability/ease of use (13) User interface/visuals (14) Flexibility, (15) Functionality Extensible/customisable) (16) Compatibility (17) Security (18) Back up and virus protection
4. Product stability -> DCB	(19) Performance levels (20) Uptime percentage (21) System usability (22) Technology and innovativeness, (23) Load/capacity
5. Processes -> PCP	(24) Internal process, (25) Project management, (26) Design/build process, (27) Training facility
6. Quality -> QLT	(28) Testing facility, (29) Product durability, (30) Performance and conformance to standards, (31) ISO/CMM certification status, (32) TQM, (33)Data Security
7. Financial/ commercial position -> FNP	(34) Sustainability, (35) Ownership structure/history, (36) Cash flow, (37) Intellectual property agreement, (38) Non-disclosure agreement, (39) Financial record disclosure with growth rate, (40) Warranties and claim policies
8. Vendor culture -> VCL	(41) Professionalism, (42) Flexibility & commitment, (43) Open/friendly, (44) Integrity, (45) Understanding the business goals & environment, (46) Proactiveness
9. Services/support -> SSP	(47) After sales service, (48) Technical support level, (49) Sales person/ account manager's competence, (50) Documentation
10. Cost -> CST	(51) One time (set-up, configuration, development) (52) On going (maintenance, support, licensing, data migration, training) (53) Total cost of ownership.

A new instrument incorporating the refined 10 criteria and 53 sub criteria was developed. The developed questionnaire was given to the said experts and again they were briefed about the purpose of this research and its scope. The experts were asked to scrutinize the questionnaire and to give their comments regarding its relevance and contents. They were also asked to critically examine the questionnaire and to give objective feedback and suggestions in regard to comprehensiveness/coverage, redundancy level, consistency and number of items in each variable.

3.4 Measures of vendor selection & hypothesis development

In view of the importance of vendor selection decision and the growing complexity, this study develops a vendor selection support framework. Based on the study of the past literature, this research primarily considers the primary criteria measured for vendor selection, which is discussed in the following section. The hypothesis are determined from these measured. Furthermore, the researcher has reviewed five vendors, which have high reputation in providing services to BFSI are considered for this research. The wide range of review of last >40 years was done to find out the importance of the identified criteria and how these were perceived by other researchers in their study

3.4.1 Vendor credibility

The reputation in the market is the most important part of vendor credibility. Reputation matters a great deal. However, reputation is built in a variety of ways and reputation relies upon is how your prospects have developed their interpretation of your reputation. Every interaction we have with our prospects builds their perception of our reputation with them. In today's world, reputation can be more important than price; customer references go a long way to establishing that. Strategic direction and existing relation are important under vendor credibility, as vendors are a part of buyer organisations strategic and long term decision and in that case, it is important for the vendors to have the vision to innovate the way you organisations like.

The other things trust and technical project management are also the factors that contribute to reputation that affects the buying decision. Trust is very important and related to vendor's credibility, as the nature of business in BFSI are very confidential in nature, where security is a main concern for the banks.

H_1: High level of vendor credibility criteria will lead to high chance of vendor selection.

3.4.2 Management & organisation

In vendor selection, any buyer will view the management and organisation as an important criterion influencing the selection process. Management & organisation refer to the physical size of the organisation, and the ethical standards in the industry, which give a perspective of the nature of the vendor organisation, and its standards. Geographic location is equally important as company size. It tells a company a lot about culture and communication requirements. For example a company would adopt a different strategy with an Asian customer than with an American customer. Geographic location also relates to culture, language and business attitudes. Other researchers' such as Keah Chhon Tan (2002) have considered the physical size as an important criterion for vendor selection. Bhutta and Huq (2002), etc. have considered geographical location as a vital factor in the selection of vendors. Maintaining ethical standard, which is a part of management & organisation and is equally important as some critics claim that too much emphasis on technology dehumanises people and minimises the importance of balancing the process with individual and organisation needs.

H_2: High level of management of organisation criteria will lead to high chance of vendor selection.

3.4.3 Technical elements

Technical element is believed to be one of the important vendor selection criteria when it comes to technology vendor selection like as in this research. Previous researchers (Kannan & Haq 2007) have suggested that technical elements determine the technical ability of vendors. The usability or the ease of use and the visuals are important sub criteria and these are consumer driven. These are more relevant to mobile banking application, where users in general will decide on user friendly applications. The security is an important feature considering on line payment transaction through mobile device. There is growing evidence that criminals are using SMS text messages in phishing scams, security has become a concern area not only on internet banking through personal computer, but through mobile banking as well.

H_3: High level of technical elements will lead to high chance of vendor selection.

3.4.4 Product stability

Product stability is an important criterion and is relevant to this research subject, which has a key influence on vendor selection. This criterion is dependant on sub criteria like performance level, uptime percentage, system usability, technology & innovativeness. System usability is the effectiveness, efficiency and satisfaction of specific products which provide specific services in specific situations. All vendors strive to create techniques that will make their products stand out from the competition. Thus innovation is a very important component of the vendor selection.

H_4: High level of Product stability will lead to high chance of vendor selection.

3.4.5 Processes

All IT vendors should have strong process for software development life cycle. More and more high technologies are adapting software development and implement process methodologies. The processes consists of internal process, project management, design & build process and training facility. The process reflects the quality standard the vendor follow and involves from employee selection, the software selection, project management methodology and even the training facility of the employees and users. A robust process comprising of all these, help the buyer to identify the right vendor.

H_5: High level of processes will lead to high chance of vendor selection.

3.4.6 Quality

Quality is an important factor considered especially within the banking & financial industry, which is driven by high quality customer services. Lin *et al* (2005) have researched on SEM approach to determine organization performance and referred that quality management practices are imperative in vendor selection strategies. Gonzales *et al* (2004) found that quality is the most significant attribute in vendor selection. Several studies have considered the quality criteria for vendor selection decision. The criterion of quality refers to testing facility, product durability, performance & conformance standards, ISO certification, documentation etc. Product durability was considered by Tracey & Tan (2001) and Krause *et al* (2001), Hemsworth *et al.* (2005) focused on ISO certification status, while TQM was emphasised by Yuzong & Liyun (2007). Product performance & conformance to standards was considered by Krause *et al* (2001).

H_6: High level of quality will lead to high chance of vendor selection.

3.4.7 Financial & commercials

The financial position of the vendor is a concern to the buyer due to the high value of technology and services and without the technological support success is difficult to achieve within the mobile banking services. Hence it has become crucial for the vendors to have a strong financial position to withstand the competition. This criterion has been discussed by many researchers within the selections of vendors. Payne 1970, Hahn *et al.* 1986, and Kraljic 1983 claimed that the financial position of the vendor and the relationship with vendor selection is important. The above claim has also been supported by researchers like Yahya and Kingsman (1999), Tan et al. (2002) etc. The Financial stability, cash flow, non-disclosure agreement, financial record disclosure etc. of the vendor also comes under this category. Choi and Hartley (1996) discussed the importance of financial records disclosure with growth rate in financial position. This shows that financial and commercials criteria has always been a matter of discussions, while selection vendor.

H_7: High level of financial position & commercial agreement will lead to high chance of vendor selection.

3.4.8 Vendor culture

The cultural and philosophical match between the company and the vendor is the foundation of a successful outsourcing relationship. The culture comprise of professionalism, flexibility & commitment, open/friendly nature, integrity, understanding the business goals and proactiveness. How well a vendor has understood the business problem and the value they bring is the key differentiator among the vendor in selection process. Moreover, as we business continued to transform and adapt new customers' and business needs, one thing remains steadfast: the commitment to integrity; thereby integrity which is a part of culture is very important in business. Therefore, cultural compatibility is one of the most important aspects of vendor evaluation.

H_8: High level of cultural match and awareness will lead to vendor selection.

3.4.9 Services & support

Service is an important factor in the technology vendor selection process. A vendor may have great technology, but unless the vendor can integrate, deploy and back it up with great customer service, service industries like BFSI may be hesitant to install it in their mission-critical operations. In this research, the core business of banking and financial service industry is customer service. Many of the researchers like Muralidharan et al. (2001), Prashinski & Benton (2004), Hsu *et al.* (2007) strongly argue that services provided by organisations have the most influence on vendor selection. The sub factor of technical support level in service was discussed by Wu bei *et al.* (2006).

H_9: High level of services & support will lead to high chance of vendor selection.

3.4.10 Cost

The criterion of cost associated with the items refer to competitive price, cost of after sales and payment terms etc. Many of the researchers claimed that cost influences the vendor selection for the organisations (Lee et al. 2001, Prahinski and Benton 2004, Chang, Wang & Wang 2007). Monahan (1988) claimed that price is the only criteria for their research related to vendor selection criteria. Previous research strongly validated the point that price contributes to vendor selection (Lee and Rosenblatt 1986). Kannan et al. (2007) considered payment terms as one of the factors in cost which influences the vendor selection.

H_{10}: Lower level of cost will lead to high chance of vendor selection.

All the hypotheses are listed in table 3.2.

Table 3.2 Hypothesis for vendor selection

H_1	High level of vendor creditability will lead to high chance of vendor selection.
H_2	High level of management and organisation criteria will lead to high chance of vendor selection.
H_3	High level of technical elements will lead to high chance of vendor selection.
H_4	High level of product stability will lead to high chance of vendor selection.
H_5	High level of processes will lead to high chance of vendor selection.
H_6	High level of quality will lead to high chance of vendor selection.
H_7	High level of financial position will lead to high chance of vendor selection.
H_8	High level of supplier culture will lead to high chance of vendor selection.
H_9	High level of services and support will lead to high chance of vendor selection.
H_{10}	Lower level of cost will lead to high chance of vendor selection.

The next sections deal with the discussions on SEM and AHP, followed by the conceptual model development for vendor selection using SEM and AHP.

3.5 SEM and AHP approach:Theoretical framework

3.5.1 Structural Equation Modeling

Structural equation modeling (SEM) is a statistical technique for testing and estimating causal relations using a combination of statistical data and qualitative causal assumptions. Structural Equation Models (SEM) allows both confirmatory and exploratory modeling, meaning they are suited to both theory testing and theory development. Confirmatory modeling usually starts out with a hypothesis that gets represented in a causal model. The concepts used in the model must then be operationalised to allow testing of the relationships between the concepts in the model. The model is tested against the obtained measurement data to determine how well the model fits the data. Structural Equation Models are most often represented graphically.

Figure 3.1 is a graphical example of a structural equation model; the details are illustrated in the conceptual frame work discussions stage in the later part of this chapter. The variables which are sub-criteria in this research are represented by rectangles and are exogenous variables and the variables which are criteria in this research are represented by ellipses and are endogenous variables.

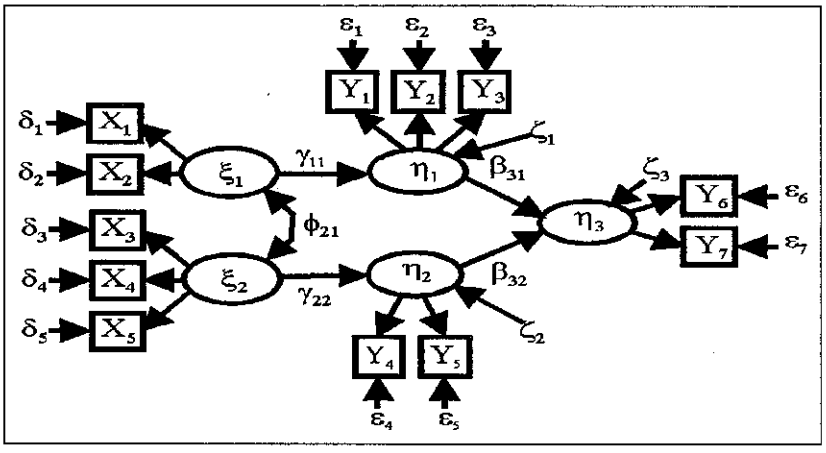

Figure 3.1 Graphical representation of SEM

Every criterion in this research is dependant on a set of sub-criteria, which are measured. The relative weighatge of each criterion is measured through the data obtained through the sub-criteria.

3.5.2 Justification for the usage of SEM

Among the strengths of SEM is the ability to construct latent variables: variables which are not measured directly, but are estimated in the model from several measured variables each of which is predicted to 'tap into' the latent variables. This allows the modeler to explicitly capture the unreliability of measurement in the model, which in theory allows the structural relations between latent variables to be accurately estimated.

Factor analysis, path analysis and regression all represent special cases of SEM. The SEM approach is used in this research to test and estimate the casual relationship using a combination of statistical data and qualitative caused assumptions. There is no difficulty in hypothesis testing in SEM because it takes the confirmatory approach rather than exploratory approach.

There are sub-criteria considered under each criterion. The response is arrived for all the sub-criteria from the people associated with BFSI and IT industries. The significance of the criteria as well as sub-criteria is tested. This is the reason why the relative weightage arrived from SEM is considered more valid than through any other approach. This model also takes measurement error into account when analysing the data statistically. SEM is capable of estimating or assessing measurement error. It can incorporate both observed and latent variables. SEM models require less reliance on basic statistical methods. Moreover there not many studies available on the usage of SEM approach for vendor selection.

3.5.3 Analytical Hierarchy Process (AHP)

The foundation of the Analytic Hierarchy Process (AHP) is a set of axioms that carefully delimits the scope of the problem environment (Saaty 1986). It is based on the well- defined mathematical structure of consistent matrices and their associated eigenvector's ability to generate true or approximate weights.

AHP was applied to measure the relative weightage of vendors on each criterion. This is calculated by using pair wise comparison matrix of vendors with respect to the relative weightage of the criteria identified for vendor selection measurement through SEM. The pair wise comparisons are made with the grade ranging from 1-9. A basic, but very reasonable assumption; if criteria A is absolutely more important than criteria B and is rated at 9, then B must be absolutely less important than A and valued at 1/9. These pair wise comparisons are carried out for all factors to be considered, usually not more than 7, and the matrix is completed.

3.5.4 Justification of usage of AHP

AHP is useful as it combines two approaches (1) the "black and white" of mathematics, and the subjectivity and intuitiveness of psychology, (2) to evaluate information and make decisions that are easy to defend.

The AHP methodology compares criteria with respect to a criterion, in a natural, pair wise mode. To do so, the AHP uses a fundamental scale of absolute numbers that has been proven in practice and validated by physical and decision problem experiments. The fundamental scale has been shown to be a scale that captures individual preferences with respect to quantitative and qualitative attributes just as well or better than other scales (Saaty 1980, 1994). It converts individual preferences into ratio scale weights that can be combined into a linear additive weight for each alternative. The resultant can be used to compare and rank the alternatives and, hence, assist the decision maker in making a choice.

3.6 Conceptual model for vendor selection using SEM and AHP

This section deals with the developing vendor selection model using Structural equation modeling (SEM-Approach) and AHP for vendor selection.

The vendor selection score is arrived at through two phases. In phase 1, the SEM model is applied to reach the relative weightage for each criterion. In phase 2, the pair wise comparison matrix using AHP was done for each vendor against the relative weightage of the criteria. For this, the responses from a smaller number of people are enough to attain the score. The generic model is of the type shown in figure 3.2 as below.

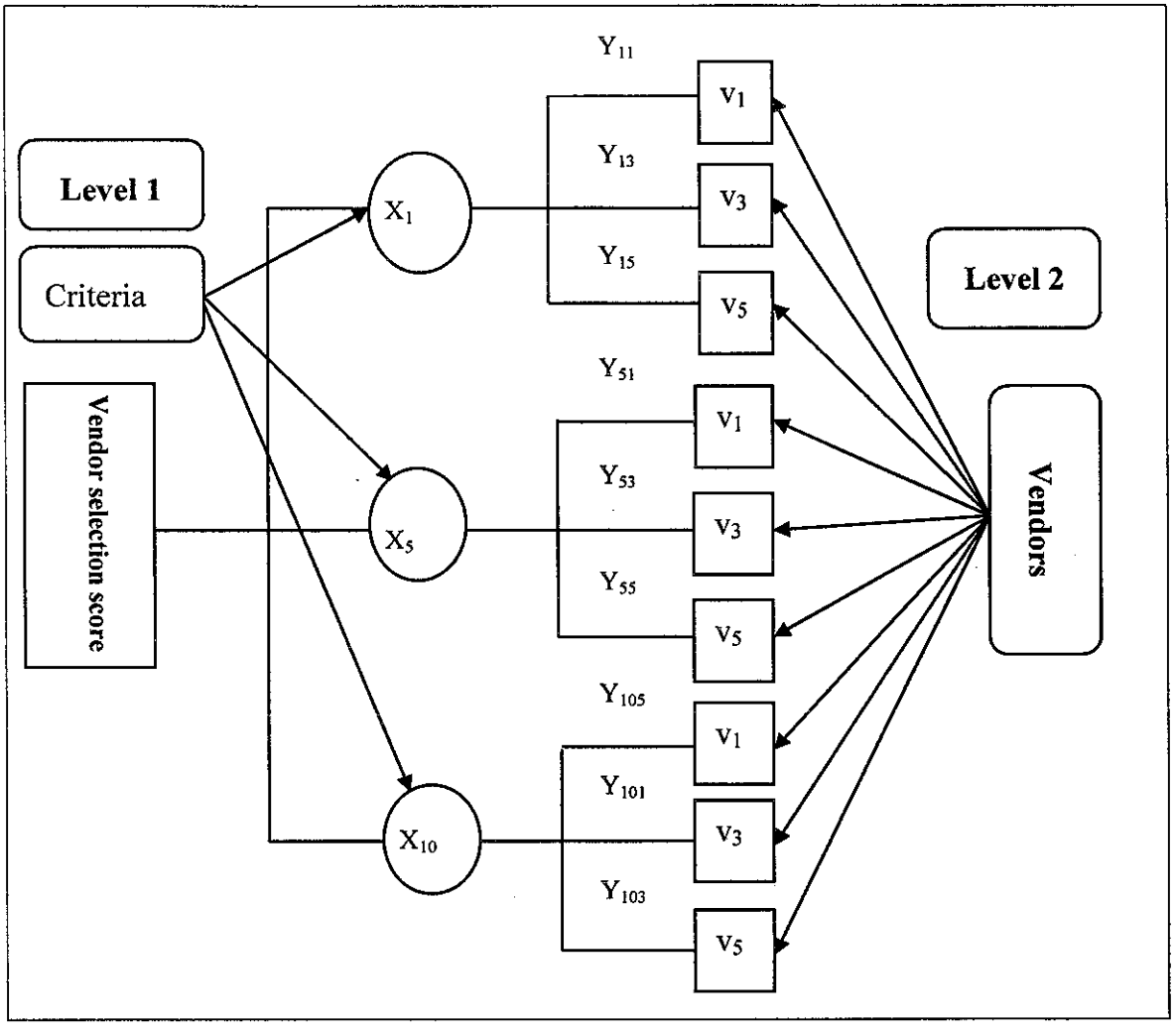

Figure 3.2 Generic model for measuring supplier selection

The first levels are the criteria for vendor selection. The second level explains the performance of each vendor with respect to each criterion. Through the first level, the relative weightage of each criteria (X_i) are calculated using the SEM model (AMOS v5.0 software was used for this) and in the second level, the relative weightage of vendors with respect to each criteria (Y_{ij}) are found out using the AHP model. These relative weightages are used to attain the vendor selection score. The SEM model denotes the relationship between criteria and vendor selection.

We can write the series of equations/ statements that summarises its configuration. The hypothesised conceptual models {Model (a) and Model (b)} with Amos notations are consisting of 10 criteria and associated sub criteria is presented Model (a)-Figure 3.3, Model (b)-Figure 3.4. The listed hypotheses (H_1, H_2....H_{10}) are also tested using "t" test.

The observed variables are modeled as linear combinations of the potential factors, plus "error" terms. The factor loading of each measure on vendor selection is tested for significance and the magnitude of each measure, will give the influence of that criteria on vendor selection. These values are used to attain the relative weightage of criteria.

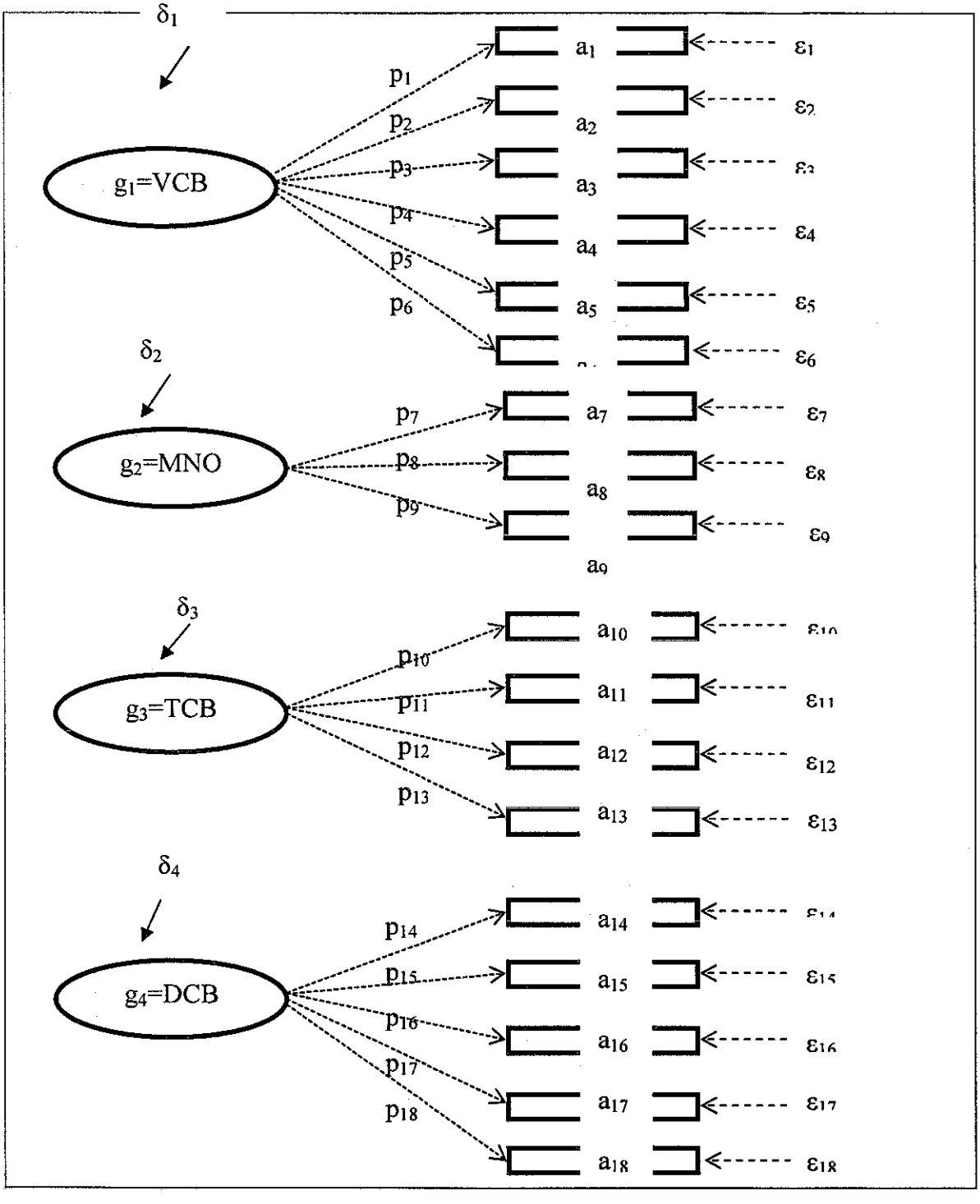

Figure 3.3 Conceptual SEM Model (a) for measuring vendor selection

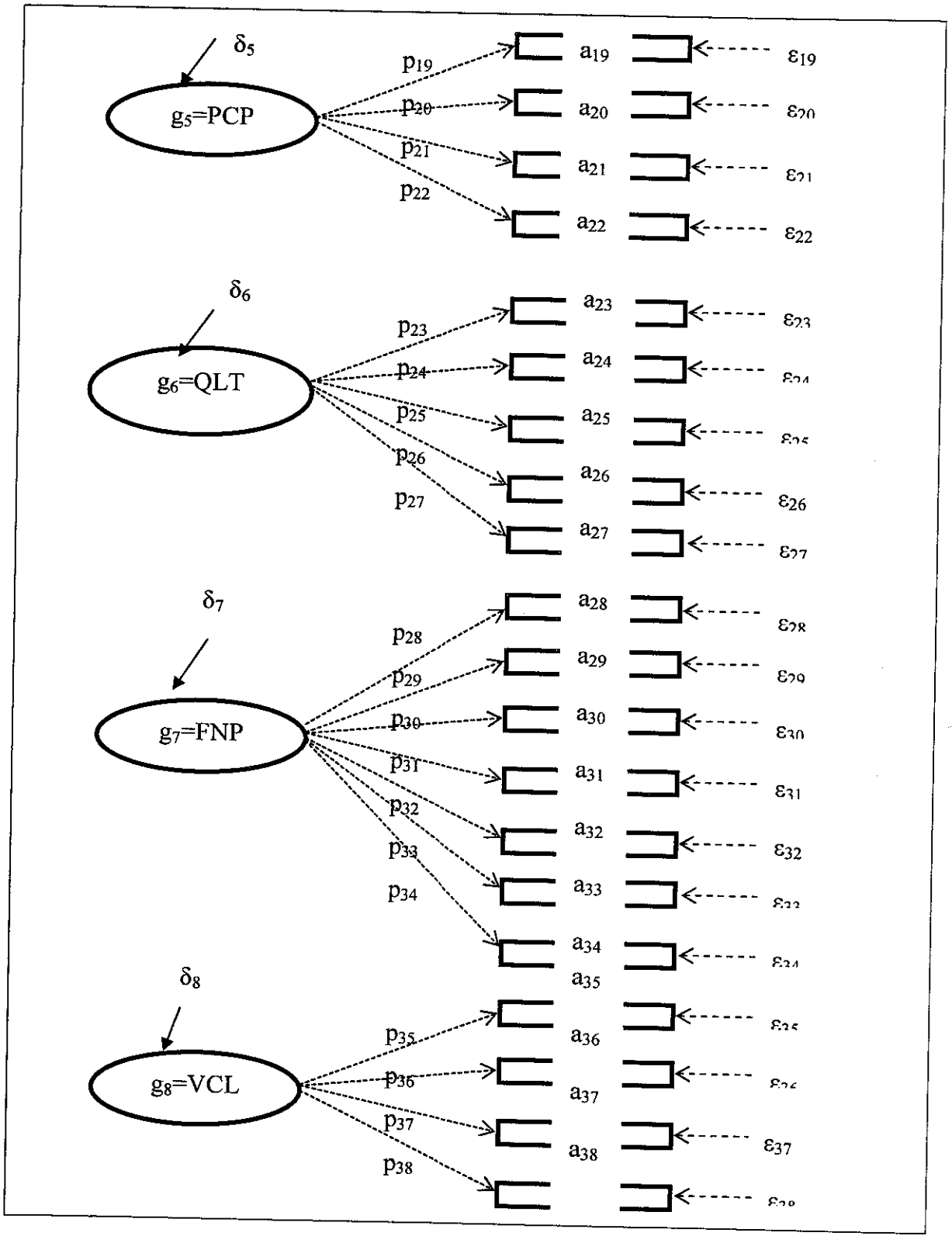

Figure: 3.3 Model (a) (continued)

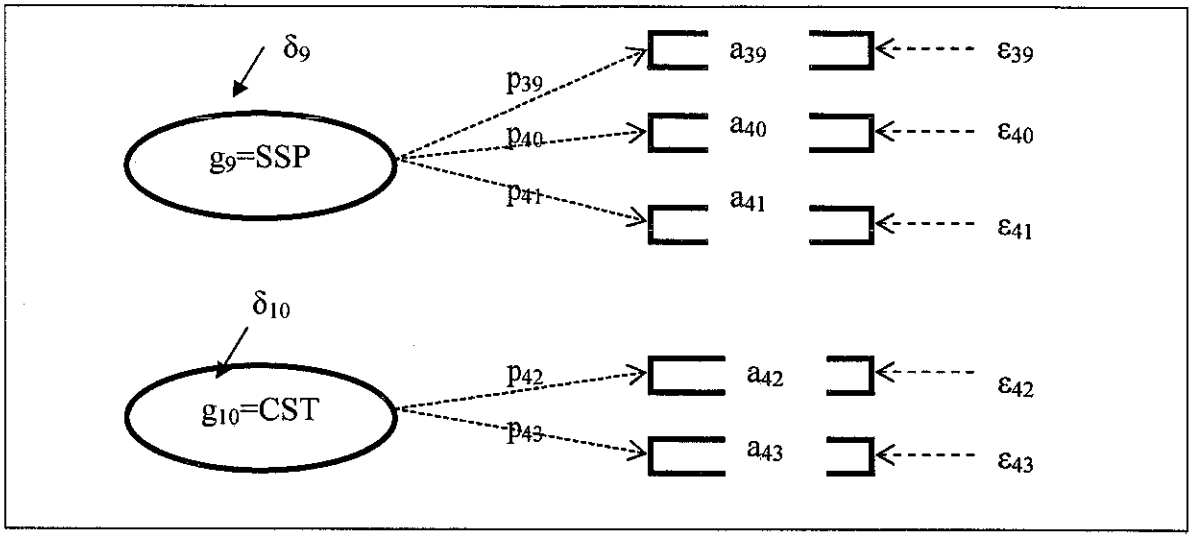

Figure 3.3 Model (a) (final)

The model includes all the possible influences on un-observed variables. The casual relationships are represented by straight single headed arrow pointed towards the effect. Independent exogenous variables i.e. sub criteria are represented by rectangle, dependent endogenous variable i.e. criteria are represented by ellipses. All the variables in the model have a unique variable name. Observed variables names i.e. sub-criteria are in the data set (a_1, a_2....a_n) and the un-observed variables i.e. criteria are as g_1, g_2....g_n. All the exogenous variables have a scale (1-7); this is accomplished by a regression co-efficient associated with the un-observed variables (the default options in AMOS). The explanation on 43 sub-criteria has been described in chapter 4, section 4.3.

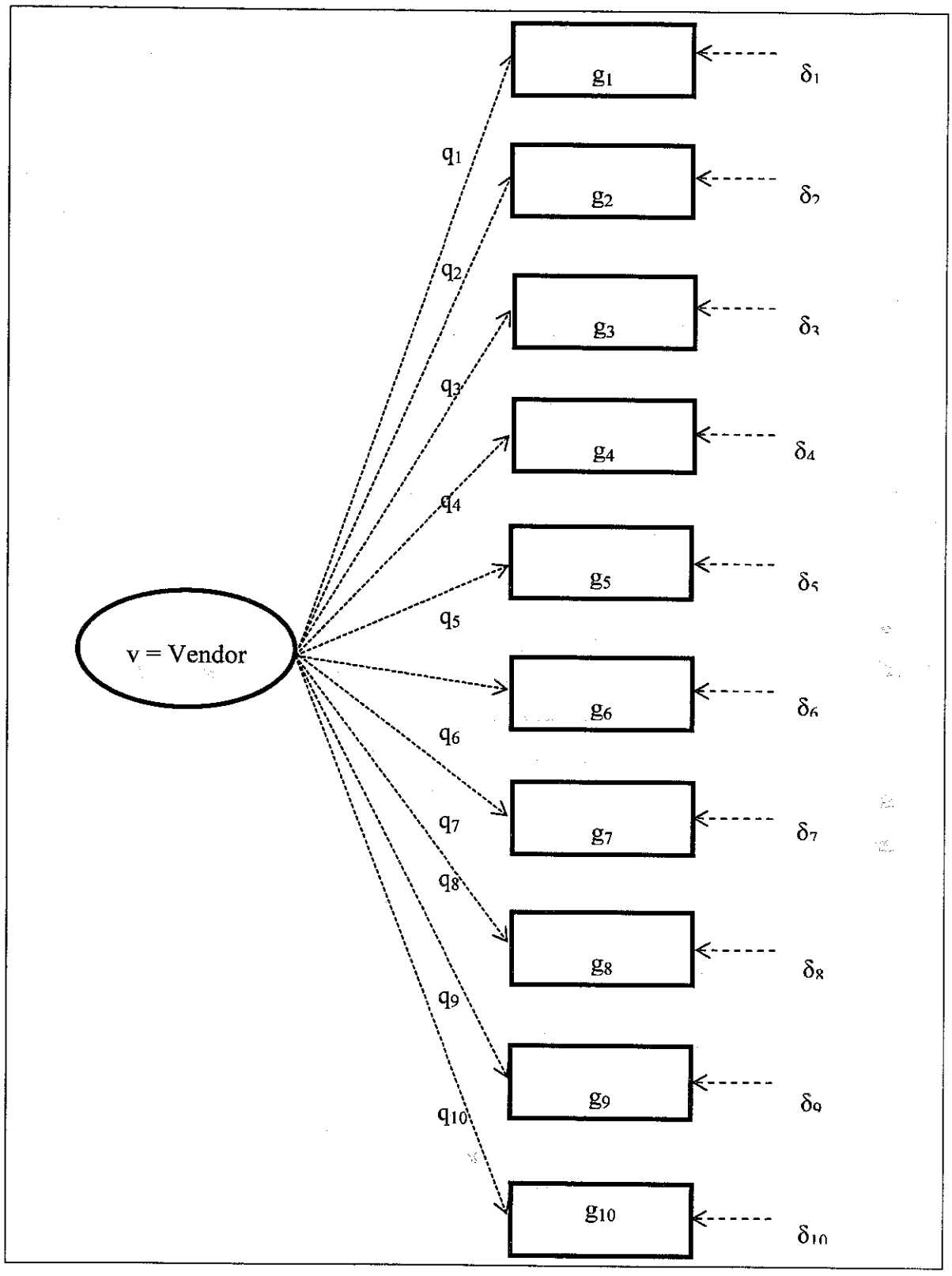

Figure 3.4 Conceptual SEM Model (b)

The criteria g_1 to g_{10} are both cause and effect variable with residual error term δ_1 to δ_{10} for vendor selection v.

We can write the series of equations/ statements that summarises its configuration. As such, we need to address the model (a) factor structure.

The model (a) factor structure equations are:

$$a_1 = p_1 g_1 + \varepsilon_1$$
$$a_2 = p_2 g_1 + \varepsilon_2$$
$$a_3 = p_3 g_1 + \varepsilon_3$$
$$\vdots$$
$$a_n = p_n g_n + \varepsilon_n$$

The equation can be written in vector form as:

$$\underset{A}{\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ \vdots \\ a_n \end{bmatrix}} = \underset{P}{\begin{bmatrix} p_1 \\ p_2 \\ p_3 \\ \vdots \\ p_n \end{bmatrix}} \begin{bmatrix} g_i \end{bmatrix} + \underset{e}{\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \vdots \\ \varepsilon_n \end{bmatrix}}$$

The above Model (a) structure can be summarised as:

$A = Pg_i + e,$

A = sub criteria $\approx a_1, a_2, a_3 \ldots .a_n$

P = model (a) factor loadings $\approx p_1, p_2, p_3 \ldots .p_n$

e = measurement error terms $\approx \varepsilon_1, \varepsilon_2, \varepsilon_3 \ldots \ldots \varepsilon_n$

$g_i = g_1, g_2, g_3 \ldots .g_{10}$

The model (b) factor structure equations are:

$g_1 = q_1V + \delta_1, g_2 = q_2V + \delta_2, g_3 = q_3V + \delta_3 \ldots\ldots g_{10} = q_{10}V + \delta_{10}$

The equation can be written in vector form as:

$$\underset{G}{\begin{bmatrix} g_1 \\ g_2 \\ g_3 \\ \vdots \\ g_n \end{bmatrix}} = \underset{Q}{\begin{bmatrix} q_1 \\ q_2 \\ q_3 \\ \vdots \\ q_n \end{bmatrix}} [v] + \underset{\delta}{\begin{bmatrix} \delta_1 \\ \delta_2 \\ \delta_3 \\ \vdots \\ \delta_n \end{bmatrix}}$$

The model (b) structure can be summarised as: $G = Qv + \delta$

Where, G = criteria $\approx g_1, g_2, g_3 \ldots g_n$

Q = Model (b) factor loadings $\approx q_1, q_2, q_3 \ldots . q_{10}$

δ =Residual error terms $\approx \delta_1, \delta_2, \delta_3 \ldots . \delta_{10}$

The significant criteria have been identified from model (b), which are effecting vendor selection in this research. From the significant criteria, the relative weightage for the criteria are calculated using the following expressions.

Relative weightage for criteria:

$$X_j = \frac{Q_j}{\Sigma Q_j}$$

Q_j is the model (b) factor loading of the "j"th criteria

ΣQ_j is the sum of all the model (b) factor loadings of the criteria.

Thus the relative weightage of criteria on vendor selection can be established by using SEM approach.

The next step involves measuring the score of the vendors in each criterion using AHP approach. A sample pair wise comparison matrix is shown in table 3.4.

Table 3.3 Sample pair wise comparison matrix

	v_1	v_2	v_3	.	.	v_j	.	.	v_M	
v_1			X_{ij}							Y_{ij}
v_2										
v_j	$1/X_{ij}$									Y_{ij}
.										
.										
v_M						X_{ij}				Y_{mj}

Above is a pair wise comparison matrix for criteria "j" for "n" number of vendors. v_{ij} is the relative weightage of vendor "i" with respect to criteria "j"; X_{ij} is the value which varies between 1 to 9 or 1 to 1/9, when we do pair wise comparison between i and j. If the (i, j) cell is a strong cell, then (j, i) becomes a weak cell and it takes the reciprocal value of the (i, j) cell. This matrix is a general matrix for the criteria j and the relative weightage of each vendor is arrived at by AHP. It denotes the scores obtained by vendor "i" in the criteria of "j". Thus the relative weightage of criteria and the relative weighatge of vendor with respect to criteria are arrived at by using SEM and AHP model.

To demonstrate the above model five vendors profile were reviewed and considered for this research those who have high reputation in providing services to BFSI. Following section discusses the brief profile about these vendors, which were found from the relevant company website.

3.7 Vendors considered for study

The developed model has been demonstrated through the consideration of an example of a retail bank in Singapore, who has operation in Malaysia as well and whose primary business is consumer banking. In order to retain and improve its customer base, the bank had implemented as well as revamped several advanced technological applications. The bank has recently upgraded its core banking and mobile banking applications through a selected vendor. There are several vendors were participated in this bid from which five vendors chosen by the bank who have a long establishment and great reputation in the banking and financial services industry. They are namely Silverlake, Sybase 365, Finnacle, Temenos, Gemalto. The bank had shortlisted these vendors on the basis of 10 important criteria as discussed in this research. All these vendors have strong experience in retail banking solutions and they have their own proprietary suite of core banking solutions which includes mobile banking application.

3.7.1 Jack Henry & Associates, Inc. ->Vendor 1

Jack Henry & Associates (NASDAQ: JKHY) was founded in 1976 and provides integrated computer systems and services for in-house and outsourced data processing to commercial banks, credit unions and other financial institutions Its core processing system namely Silverlake is an IBM-I based systems. JKHY has it's headquarter in Monett, USA, have worldwide offices and market capitalisation of US $ 2.89 B The company has strategic relationship with IBM Corporations.

3.7.2 Temenos-> Vendor 2

Founded in 1993 and listed on the Swiss stock exchange (SIX: TEMN), Temenos group is the leading provider of banking software systems to retail, corporate, universal, private, Islamic and microfinance & community banks. Headquarter in Geneva and with more than 60 offices in 41 countries, Temenos serves over 1,000 financial institutions in more than 125 countries across the world. Temenos cutting edge products provide advanced technology and rich functionality, incorporating best practice processes that leverage Temenos' experience in over 600 implementations around the globe.

3.7.3 Sybase365-> Vendor 3

Sybase an SAP company creates technology that enables the unwired enterprise by delivering enterprise and mobile infrastructure. Sybase m-commerce 365 provides an end-to-end mobile commerce solution for banks, financial institutions, mobile operators, independent service providers and merchants. Its Headquarter is in the USA and Sybase has over 60 worldwide offices in different countries.

3.7.4 Gemalto -> Vendor 4

Gemalto is a world leader in digital security and offer mobile banking solutions, which provides a full range of secure and easy-to-use banking and payment options. Headquarter in Texas, USA and is valued at USD 3 billion in 2010. With over 10,000 employees, 87 sales and marketing offices worldwide, 13 R & D centers. Gemalto mobile banking services have been designed to integrate easily with the existing mobile network and banking infrastructure.

3.7.5 Finnacle-> Vendor 5

Finnacle a product of Infosys technologies Ltd (NASDAQ: INFY) is a global leader in the "next generation" of IT and consulting. Finnacle mobile banking solution empowers retail and corporate banking customers with access to banking service through SMS, GPRS/3G and USSD-enabled handsets, leveraging a single platform. Headquartered in India, Infosys has 50 offices and over 100,000 employees across the globe.

3.8 Summary

In this chapter all the sequence and several stages have been described in the research to successfully accomplish the objectives of the research. The criteria and sub criteria have been identified, which were very important for data collection for the research.

Through the conceptual model which is a prototype, the researcher has discussed about different steps involved in vendor selection using SEM and AHP. In this research, with the help of meeting and discussions with the experts and the relevant literatures, technical journals, white papers etc. the criteria and sub-criteria for vendor selection have been identified; with regards to this point that, considering all the criteria for under vendor selection is impossible; the important criteria have been extracted by expert judgment. The evaluation and determination of weight of each vendor have been done based on these criteria. The target populations as BFSI, IT industries and freelance senior consultants servicing BFSI have been identified to circulate the questionnaire. Professionals primarily in Malaysia, Philippines, Singapore, Indonesia and India were targeted for their necessary inputs on the questionnaire.

The next chapter explained the model through a real life example and fulfills the research objective of vendor selection using SEM and AHP approach.

CHAPTER 4

VENDOR SELECTION MODEL USING SEM & AHP

4.1. Chapter overview

This chapter discusses the data collection and data analysis and application of SEM and AHP to achieve the objective. The developed hypothesis and the models were tested in this chapter taking the five vendors, which haven been discussed in the previous chapter, as an example. This chapter concludes by computing vendor selection score for each vendor.

4.2 Data collection

The data collection process for this research was performed through a self-administered questionnaire to address the research question. The researcher has used the 10 listed vendor selection criteria (as independent variables or constructs) and their corresponding specific set of 53 sub-criteria to start with, with the possibility of revising during the study. Thus the content validity and face validity have been ensured in the initial stages of questionnaire development. The questionnaire has been demonstrated in appendix 1. The self-administered research questionnaire accompanied by an informational cover letter was primarily mailed or emailed to the professionals and experts. The experts were asked rate the significance of each sub criteria on a seven-point Likert scales as per the rating mentioned in below table 4.1.

Table 4.1 Seven point scale

1	Very negligible
2	Negligible
3	Not negligible
4	Neither important/ nor negligible
5	Slightly important
6	Important
7	Very important

The responses to the questions were collected and values were tabulated. This has been done to arrive at the relative weightage for the criteria. The respondents were mainly from the banking & financial sector who are directly or indirectly involved in decision making (25%), followed by managers and senior managers in information technology industry, who are involved financial related software development life cycle in (50%), and technical presales persons form the software vendors who are involved in technical proposal analysis and proposal preparation (25%). The experts in the IT industry were chosen as they have good insights about the banks requirements and these experts are involved either to support, cutomsation of banks existing application or developing new applications base don bank's requirement. These experts involve business analyst, who are the functional experts on relevant domain, who are involved in requirement gathering, analysis, feasibility study, analysis the return on investment etc, as well as technical experts, who are involved into technical architecture designing, technical development etc. More than 80% respondents were managers or senior managers. The high hierarchical level of respondents enhances the validity of the results, since they are more likely to be familiar with organisations activity related to information technology and its impact on right vendor selection. Respondents average number of years spent in the industry and in relevant technical areas are > 7 years. The below table 4.2 shows the distribution and summary of responses.

Table 4.2 Survey response rate

	Banking & financial industry / Information technology industry	*Total*
Total number of questionnaires	250	100%
1. Total completed questionnaires	100	40%
1.1 Total valid questionnaires for data analysis	97	39%
1.2 Total late responses	5	2%
2. Total incomplete questionnaires	3	1.2%
Response rate		40%

A total of 250 questionnaires were distributed, and only 105 completed surveys were returned, of which 3 surveys were unusable. The 5 late responses were not taken into consideration for the data analysis. The overall response rate was 40%. Byrne (1998) points out that CFI and incremental-fit index (IFI) are more appropriate when the sample size is small, as in this case.

Microsoft excel v10.0 was used as a tool to generate the database, since it is the general application tool in the enterprise. The database was constructed using this tool. Excel, provide the following useful business techniques:

- Arithmetical formulate to ensure consistency in calculation
- Data sort, where data can be broken down into manageable segments and used to identify certain aspects of a large volume of data.
- Audit tools; precedents and dependent variables, where interrelationship between certain sets of data can be identified and used as a test of the logical structure of the data.
- Auto filters, which allow data to be analysed and grouped by different categories.
- Pivot tables and data mining, to probe the underlying source data and present data in a graphical format.

To find the relative weightage of vendors with respect to each criteria, the consensus of senior management was taken, who has long experience in IT and BFSI in technical field as well as vendor selection committee. This was considered in the development of pair wise matrices.

4.3 Variable and measurement

It was necessary to remove the following sub criteria because as per respondents, some of these were either overlapping with others or may not be very relevant to mobile banking and also to achieve the uni-dimensionality;

- ✓ From management & organisation - account management, employees.
- ✓ From technical elements- user interface, extensible, backup and virus protection.
- ✓ From Quality- product durability, audits/certification.
- ✓ From vendor culture- open/friendly, proactiveness.
- ✓ From services & support – sales person/account manager's competence.

This was a valid approach as reducing the number of sub-criteria or merged some of the sub criteria with others, helps to increase the stability of the criteria estimates and is often necessary when the ratio of criteria to sample size is large. The final model was based on 10 criteria and 43 sub criteria. To show the quality of the research design, reliability and convergent validity, the confirmatory factor analysis was performed and respective factors were taken for item analysis to measure the reliability of the scale items.

4.3.1 Reliability

Reliability is an essential pre requisite for data validation. There are several methods to establish the reliability of measuring instruments of which internal consistency method is considered the most effective.

Internal consistency is typically a measure based on the co-relations between different items on the same test (or the same sub scale or a larger test). It measures whether several criteria that propose to measure the same general construct produce the similar scores. Internal consistency is usually measure with Crobanch's α. A commonly accepted rule of thumb for describing internal consistency is $0.80 \geq \alpha \geq 0.70$. Cronbach's α test were performed on the ten constructs and the full model in this research. Based on the co-efficient values, the items tested were deemed reliable for this research i.e. they were > 0.70. This is listed in below table 4.3.

Table 4.3 Results of constructs

Criteria	**Code**	**No. of items**	**Mean**	**SD**	**Cronbach's alpha**	**R^2**
Vendor credibility	VCB	6	4.6431	0.65315	0.789	0.764
Management & organisation	MNO	3	4.6689	0.64160	0.765	0.738
Technical element	TCB	4	4.6586	0.54680	0.785	0.834
Product stability	DCB	5	4.5700	0.62507	0.819	0.877
Processes	PCP	4	4.7405	0.93580	0.824	0.798
Quality	QLT	4	4.6454	0.64939	0.848	0.868
Financial/commercial position	FNP	7	4.6116	0.66451	0.771	0.678
Vendor culture	VCT	4	4.5457	0.89252	0.825	0.825
Services/support	SSP	3	4.7635	0.65835	0.832	0.606
Cost	CST	3	4.8532	0.75846	0.854	0.670

Convergent validity and co-efficient of determination are explained in below sections.

4.3.2 Convergent validity

Convergent validity is the degrees to which the various approach to construct measurement are similar to other approaches that they theoretically should be similar. Once CFA model fit was established for each constructs in the study, and the convergent validity was assessed based on the significance of the coefficients.

If these are significant, then the indicators are effectively converging to measure the same construct (Anderson and Gerbing, 1988). The coefficients for all indicators in the constructs should be large and significant ($p<0.01$). This was indeed the case. In addition, since each of the CFA models demonstrated good fit, each construct is uni-dimensional. This is shown in figure 4.11. Moreover, the variable estimate and its respective t-values prove that all the variables attained significance level at $p<0.01$. This is show in appendix 2. The models are portrayed in the figures 4.1 till 4.11.

4.3.3 Co-efficient of determination

R^2 (coefficient of determination) is a statistic that provides some information about the goodness of fit of a model. In regression, the R^2 coefficient of determination is a statistical measure of how well the regression line approximates the real data points. In simple linear regression, the coefficient of determination ranges from 0 to 1 is considered as regression line fits the data, which is in this case. This is shown in above table 4.3.

Vendor credibility

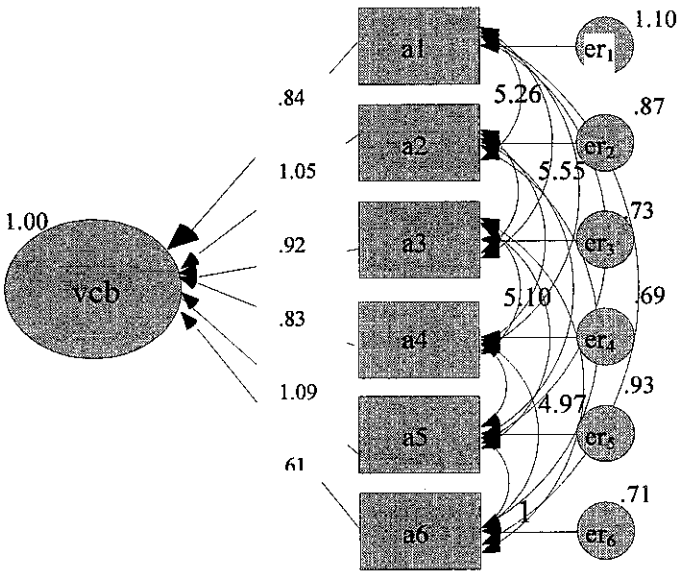

Figure 4.1 Amos Model (a) g_1

Management & Organization

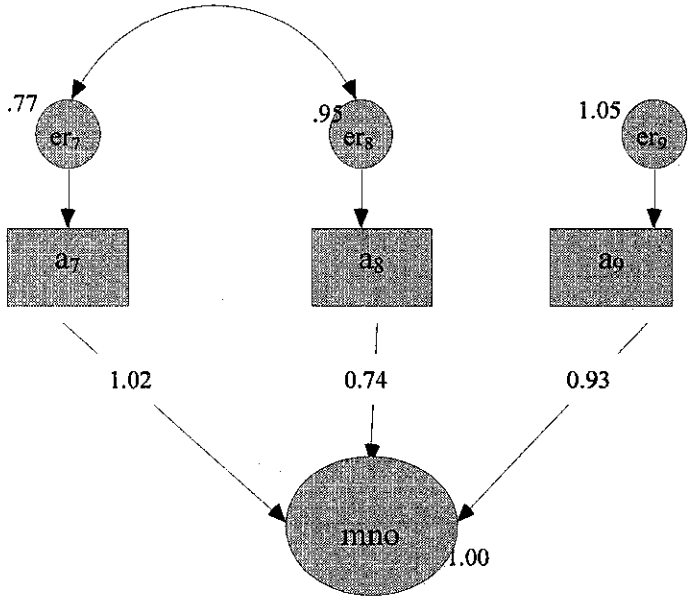

Figure 4.2 Amos Model (a) g_2

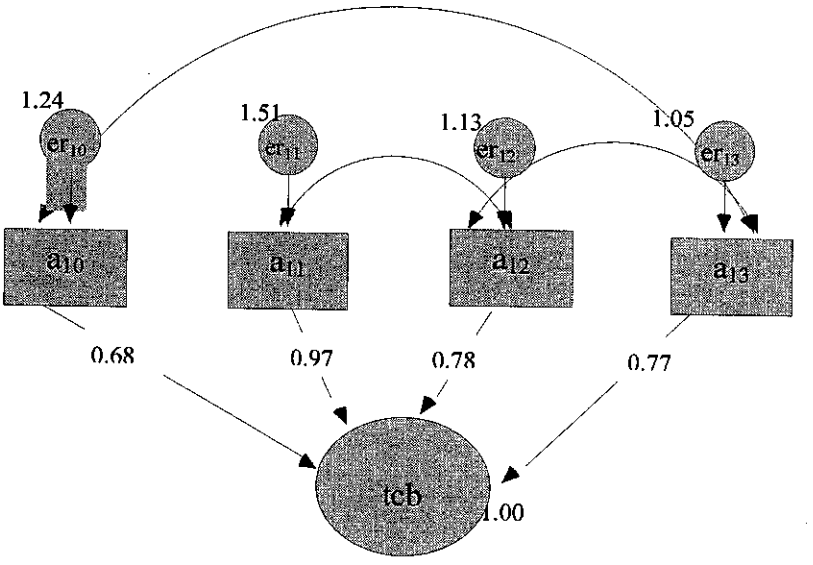

Figure 4.3 Amos Model (a) g_3

Delivery capability

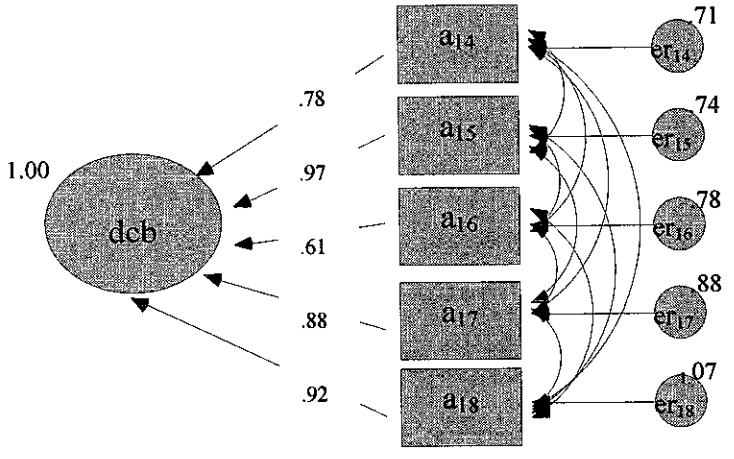

Figure 4.4 Amos Model (a) g_4

Processes

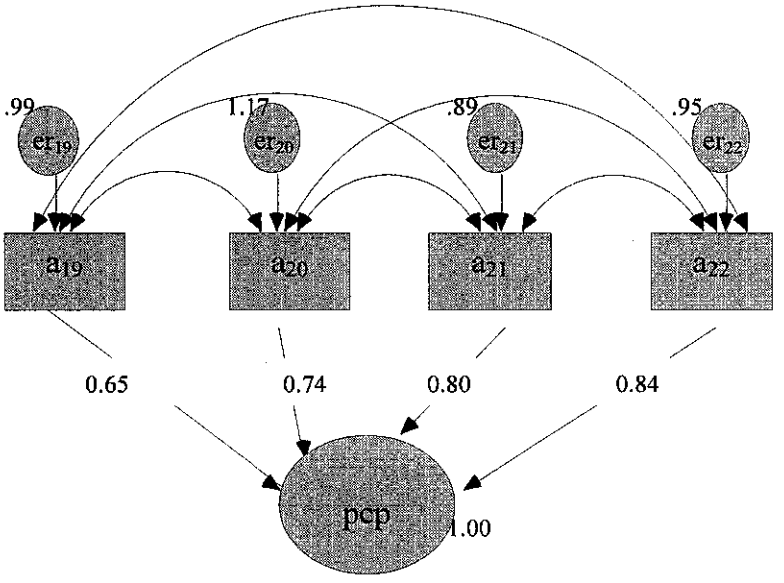

Figure 4.5 Amos Model(a) g_5

Quality

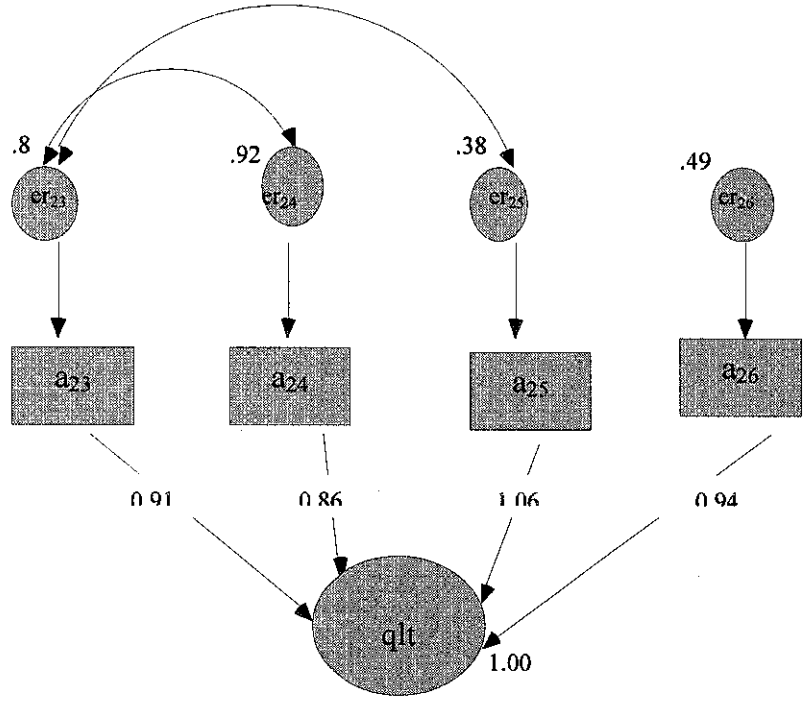

Figure 4.6 Amos Model(a) g_6

Financial & commercials

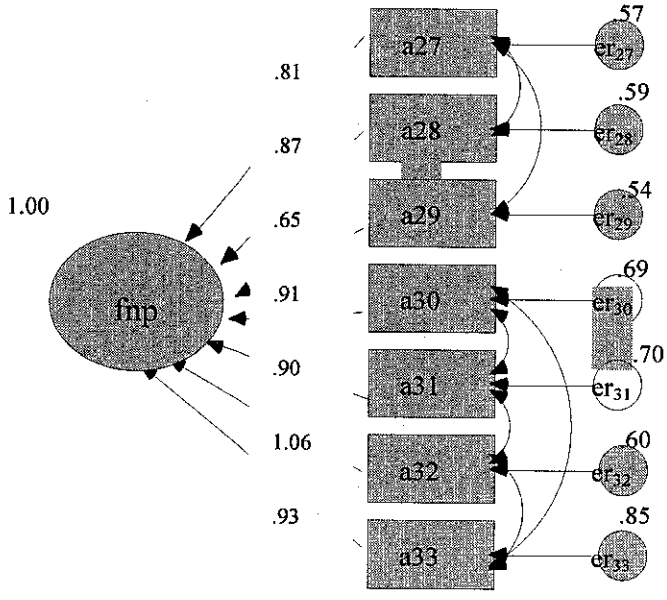

Figure 4.7 Amos Model (a) g_7

Vendor culture

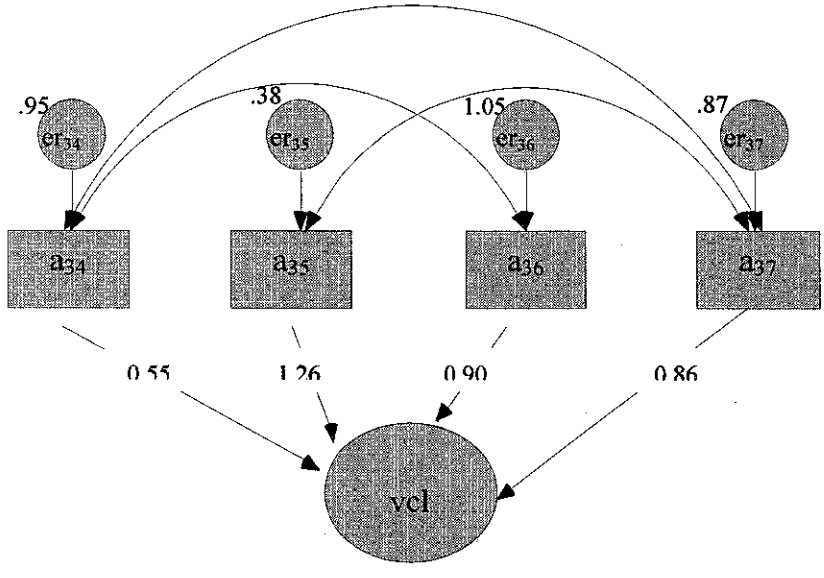

Figure 4.8 Amos Model (a) g_8

Services & support

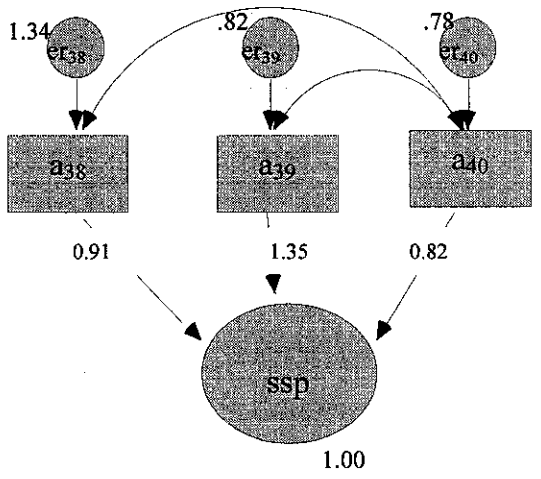

Figure 4.9 Amos Model (a) g_9

Cost

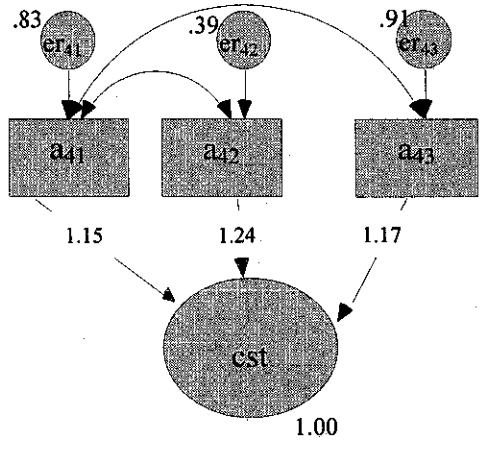

Figure 4.10 Amos Model (a) g_{10}

Model (b)

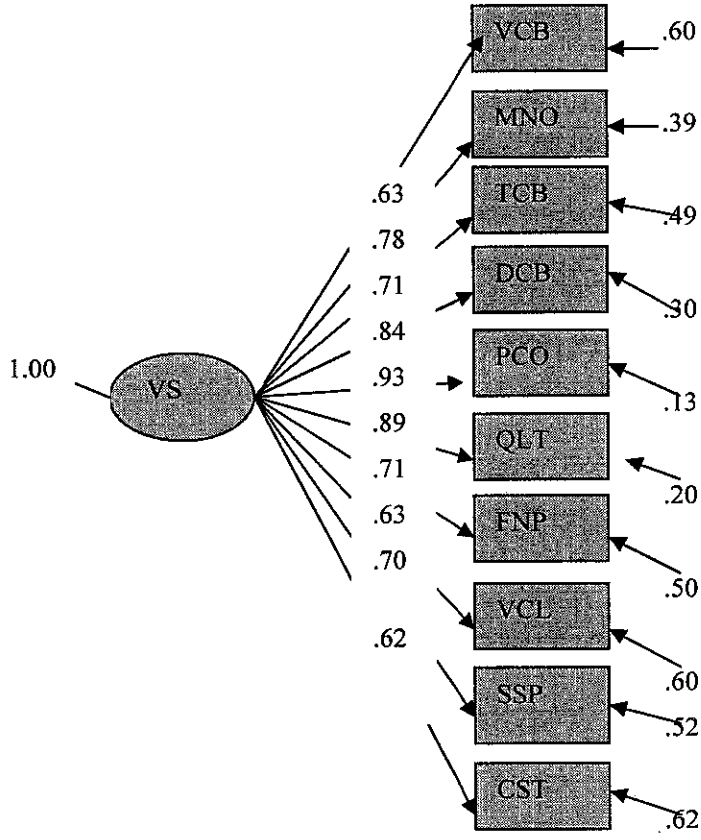

Figure 4.11 Relative weightage of each criteria

The figures 4.1 to 4.10 termed as Model (a) demonstrate the Amos software analysis on each criteria starting from Group one (g1) to Group ten (g10); the groups are structured as vendor credibility (VCB-g_1), management and organisation (MNO-g_2), technical element (TCB-g_3), product stability (DCB-g_4), processes (PCP-g_5), quality (QLT-g_6), financial & commercials (FNP-g_7), vendor culture (VCL-g_8), services and support (SSP-g_9), cost (CST-g_{10}). Data obtained through Model (a), have been utilised in Model (b) as in figure 4.11 to find out the relative weightage of each criteria.

4.4 Empirical results

Assessment of fit is a basic task in SEM modeling: forming the basis for accepting or rejecting models and, more usually, accepting one competing model over another. Recently considerable controversy has flared up concerning fit indices. Some researchers do not believe that fit indices add anything to the analysis (e.g., Barrett, 2007) and only the chi square should be interpreted. The worry is that fit indices allow researchers to claim that a miss-specified model is not a bad model. Others (e.g., Hayduk, Cummings, Boadu, Pazderka-Robinson, & Boulianne, 2007) argue that cutoffs for a fit index can be misleading and subject to misuse. Most analysts believe in the value of fit indices, but caution against strict reliance on cutoffs. Kenny, Kaniskan, and McCoach (2011) have argued that fit indices should not even be computed for small degrees of freedom models.

The conceptual model was tested using SEM (casual model), which is performed AMOS v6.0. The model (a) has resulted that the variables are valid due to indicator parameter estimates and their statistical significance. This is discussed in details in the below section.

The Model (a) includes the endogenous dependent observed variables (A) related to:

- Vendor credibility (a_1 to a_6),
- Management & organisation (a_7 to a_9),
- Technical elements (a_{10} to a_{13}),
- Product stability (a_{14} to a_{18}),
- Processes (a_{19} to a_{22}),
- Quality (a_{23} to a_{26}),
- Financial/Commercial position (a_{27} to a_{33}),
- Vendor culture (a_{34} to a_{37}),
- Services/support (a_{38} to a_{40}),
- Cost (a_{41} to a_{43}).

4.4.1 Goodness-of-fit model test

A goodness-of-fit model test was conducted before analyzing the proposed hypothesis. This was administered by meeting the following measurement criteria:

a) Absolute fit measure: Measuring overall fit models by examining chi square statistics, goodness-of-fit index (GFI) and root mean square error of approximation (RMSEA).
b) Incremental fit measure: these are used to compare the proposed model with those specified by researchers by examining normed fit index (NFI), adjusted good-of-fit index (AGFI) and comparative fit index (CFI).

The results are in table 4.4. Though Chi square (χ^2) is the most important point to be met in goodness-of-fit model, χ^2 test is widely recognized as problematic (Joreskog, 1969). It is sensitive to sample size and it becomes more and more difficult to obtain null hypothesis as the number of cases increases. The table shows that chi square (χ^2) is 15.10 with p-value is 0.031. The chi square 15.10 does not meet the recommended criteria in a goodness-of-fit test, whereas goodness-of-fit test based on absolute fit measure criteria such as GFI $\approx$ 1.083, passes as recommended. Similarly, the goodness-of-fit measure based on incremental fit measure such as NFI $\approx$0.912 and CFI$\approx$ 0.916 meets the recommended criteria.

Table 4.4 Fit indices table of SEM

Fit measure	Recommended values	Fit indices of model
χ^2 / df	$\leq$5.00	1.258
CFI	$\geq$0.9	0.916
RMSEA	$\leq$0.08	0.068
GFI	$\geq$0.9	1.083
NFI	$\geq$0.90	0.912
AGFI	$\geq$0.90	0.930

4.4.2 Hypothesis testing

This was already mentioned that the construct score acts as an observed variable or criteria in model (b). The results of model (b) exhibit that all the path co-efficient values and critical ratio are within range. All hypotheses are supported i.e. all direct paths are significant and positive (C.R. values > +/-1.96; p-value < 0.05). Thus the structural model supports all the ten hypothesis of the proposed model as listed in table 4.5. The hypotheses are represented in the structural model as shown in Figure 4.11.

Table 4.5 Results of hypotheses

Casual path	*Hypotheses*	*Point estimation*	*t-value*	*Evidence*
Vendor credibility -> vendor selection	H_1	0.63	8.46	Supported
Management & organisation -> vendor selection	H_2	0.78	11.24	Supported
Technical element -> vendor selection	H_3	0.71	9.95	Supported
Product stability-> vendor selection	H_4	0.84	12.53	Supported
Processes -> vendor selection	H_5	0.93	15.01	Supported
Quality-> vendor selection	H_6	0.89	13.96	Supported
Financial position -> vendor selection	H_7	0.71	9.84	Supported
Vendor culture -> vendor selection	H_8	0.63	8.43	Supported
Services/support -> vendor selection	H_9	0.70	9.62	Supported
Cost -> vendor selection	H_{10}	0.62	8.22	Supported

The influence of vendor credibility, technical element, product stability, processes, quality, financial/commercial position, vendor culture, services/support, and cost on vendor selection has been proved by hypothesis H_1, H_2, H_3, H_4, H_5, H_6, H_7, H_8, H_9, and H10. So the proposed model explained a significant percentage of variance in vendor selection. Thus, the SEM model ensures that the proposed model is consistent and gains better acceptance level.

4.5 Calculation of Relative Weightage of criteria (X_j)

The Model (b) factor structure equations comprising ten criteria have been discussed in earlier chapter. The criteria are described as below:

- ✓ g_1 represents the criteria "Vendor credibility"
- ✓ g_2 represents the criteria "Management & organisation"
- ✓ g_3 represents the criteria "Technical elements"
- ✓ g_4 represents the criteria "Product stability"
- ✓ g_5 represents the criteria "Processes"
- ✓ g_6 represents the criteria "Quality"
- ✓ g_7 represents the criteria "Financial/commercial position"
- ✓ g_8 represents the criteria "Vendor culture"
- ✓ g_9 represents the criteria "Services & support"
- ✓ g_{10} represents the criteria "Cost"

The Model (b) factor structure equations can be written which comprise ten criteria as:

$$g_1 = q_1V + \delta_1, g_2 = q_2V + \delta_2, g_3 = q_3V + \delta_3 \ldots\ldots\ldots g_{10} = q_{10}V + \delta_{10}$$

Model (b) factor loadings $\approx q_1, q_2, q_3 \ldots q_{10}$

Residual error terms $\approx \delta_1, \delta_2, \delta_3 \ldots\ldots \delta_{10}$

Based on the values of Model (b) factor loadings and residual error terms, the above mentioned factor structure equations comprise ten criteria as:

$$g_1 = 0.63\ v + 0.60;$$
$$g_2 = 0.78\ v + 0.39;$$
$$g_3 = 0.71v + 0.49;$$
$$g_4 = 0.84v + 0.30;$$
$$g_5 = 0.93v + 0.13;$$
$$g_6 = 0.89v + 0.20;$$
$$g_7 = 0.71v + 0.50;$$
$$g_8 = 0.63v + 0.60;$$
$$g_9 = 0.70v + 0.52;$$
$$g_{10} = 0.62v + 0.62$$

The equation can be written in vector form as:

$$\begin{matrix} G \\ \begin{bmatrix} g_1 \\ g_2 \\ g_3 \\ g_4 \\ g_5 \\ g_6 \\ g_7 \\ g_8 \\ g_9 \\ g_{10} \end{bmatrix} \end{matrix} = \begin{matrix} Q \\ \begin{bmatrix} 0.63 \\ 0.78 \\ 0.71 \\ 0.84 \\ 0.93 \\ 0.89 \\ 0.71 \\ 0,63 \\ 0.70 \\ 0.62 \end{bmatrix} \end{matrix} [v] + \begin{matrix} \delta \\ \begin{bmatrix} 0.60 \\ 0.39 \\ 0.49 \\ 0.30 \\ 0.13 \\ 0.20 \\ 0.50 \\ 0.60 \\ 0.52 \\ 0.62 \end{bmatrix} \end{matrix}$$

Where, G = criteria $\approx g_1, g_2, g_3 \ldots g_n$

Q = Model (b) factor loadings $\approx q_1, q_2, q_3 \ldots q_{10}$

δ =Residual error terms $\approx \delta_1, \delta_2, \delta_3 \ldots \delta_{10}$

Relative weightage for criteria can be calculated using $X_j = \frac{Q_j}{\Sigma Q_j}$

Q_j is model (b) factor loading of the j^{th} criteria and ΣQ_j is the sum of all the model (b) factor loadings of the criteria. Below table 4.6 shows the relative weightage of all the 10 criteria.

Table 4.6 Relative weightage of all the criteria

Sl no	Criteria	Relative weightage	Rank
1	Vendor credibility	0.63/7.44 = 0.0847	8 or 9
2	Management & organisation	0.78/7.44 = 0.1048	4
3	Technical element	0.71/7.44 = 0.0955	5
4	Product stability	0.84/7.44= 0.1129	3
5	Processes	0.93/7.44 = 0.1250	1
6	Quality	0.89/7.44 = 0.1196	2
7	Financial/commercial position	0.71/7.44 = 0.0954	6
8	Vendor culture	0.63/7.44 = 0.0847	9 or 8
9	Services/support	0.70/7.44 = 0.0941	7
10	Cost	0.62/7.44 = 0.0833	10

The analysis clearly show that in the technology vendor selection, the cost is not the most important criteria; rather technical process of the vendor followed by the quality offered by the vendor and the stability of the product, which are the top three detrimental criteria to select a technology vendor. However, the relative weightage scores for all the criteria are found. In order to find the relative weightage of vendors in ten criteria, AHP approach was used, which is discussed in below section.

4.5 Relative weightage of vendor

The researcher has used the AHP approach to find the relative weightage of vendors in ten criteria which is, as discussed in the following section.

4.5.1 Calculation of Vendor's Relative Weightage

The relative weightage of vendor on each criterion was calculated by using pair wise comparison matrix of vendors with respect to criteria identified for vendor selection measurement. The pair wise comparison matrixes were developed for five mobile banking application vendors upon ten criteria.

There are many ways to obtain the preference from the decision maker, but the measurement scale proposed by Saaty (2000) is most commonly used. The table 4.7 provides a quick reference of the decision maker judgment and preference of criteria with pair wise comparisons. The measurement scale enables the decision makers to determine the degree to which each single criterion is preferred in comparison with others. This measure scale included 1-9 scale points, each point represents different degree of preference.

Table 4.7 Saaty's rating scale

Intensity of importance	**Definition**	**Explanation**
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favour one over the other.
5	Much more important	Experience and judgement strongly favour one over the other.
7	Very much more important	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Immediate vales	When compromise is needed

In order to find the relative weightage of the vendors with respect to each criterion, the consensus of the top managements of the banks and IT organisations involved in strategic direction, vendor selection, and project managers were considered; this has assisted the researcher in the development of pair wise matrices. The five vendors, who were identified by the bank, have a long experience in the related field and have their own specialty and strategy to manage their business. Pair wise matrices were developed according to consensus reached by the people as per Saaty's scale. The relative weightage of the vendor with respect to each criterion was calculated by using Eigen value method. A sample pair wise matrix used for calculation to arrive at the relative weightage of vendor with respect to Management & Organisation criteria is discussed in the following section.

4.5.2 Vendor relative weightage in Management & Organisation

The pair wise comparison matrix for the factor of "Management & Organisation" for five vendors is shown in table 4.8. The vendors are denoted in the pair wise matrices are as:

Vendor 1 – Jack Henry & associates, Inc.

Vendor 2 –Temenos

Vendor 3 –Sybase365

Vendor 4 –Gemalto

Vendor 5 –Finnacle

Table 4.8 Pair wise comparison matrix for MNO

	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	3	3	5	7
Vendor 2	1/3	1	3	3	7
Vendor 3	1/3	1/3	1	7	7
Vendor 4	1/5	1/3	1/7	1	1
Vendor 5	1/7	1/7	1/7	1	1

It can be referred from the above table that vendor 1 is moderately preferred over vendor 2 and vendor 3. Vendor 1 is strongly preferred over vendor 4 and very strongly preferred over vendor 5. Vendor 2 is moderately preferred over vendor 3 and vendor 4. Vendor 2 is strongly preferred over vendor 5. Vendor 3 is very strongly preferred over vendor 4 and vendor 5. Based on the example of pair wise comparison as described in chapter 3 (table 3.3), vendor 2 gets the value 1/3 compared to vendor 1. It can be inferred that vendor 2 is not so moderately preferred over vendor 1 with respect to this factor. Vendor 3 gets the value of 1/3 compared to vendor 1 and vendor 2. It can be inferred that vendor 3 is not so moderately preferred over the vendor 1 and vendor 2 with respect to this factor. Vendor 4 gets the value 1/5 compared to vendor 1, 1/3 compared to vendor 2, 1/7 compared to vendor3. It can be inferred that vendor 4 is not so strongly preferred over vendor 3 with respect to this factor. Vendor 5 gets the value of 1/7 compared to vendor 1, vendor 2 and vendor 3. It can be inferred that vendor 5 is not so strongly preferred over vendor 1, vendor 2 and vendor 3 with respect to this factor.

The next step is to calculate the priority vectors for all the vendors. The normalised principal Eigen vector is also called priority vector. Since it is normalised, the sum of all elements in priority vector is 1. The priority vector shows relative weights among the alternatives to be compared. 5 by 5 reciprocal matrix from paired comparison is demonstrated in table 4.9.

Table 4.9 Paired comparison

	vendor1	vendor2	vendor3	vendor4	vendor5
vendor1	1.00000	3.00000	3.00000	5.00000	7.00000
vendor2	0.33333	1.00000	3.00000	3.00000	7.00000
vendor3	0.33333	0.33333	1.00000	7.00000	7.00000
vendor4	0.20000	0.33333	0.14286	1.00000	1.00000
vendor5	0.14286	0.14286	0.14286	1.00000	1.00000

The researcher used synthesises judgements as in the below table 4.10. The sum of each column of the reciprocal matrix shown in table 4.10.

Table 4.10 Summation of reciprocal matrix

	vendor1	vendor2	vendor3	vendor4	vendor5
vendor1	1.00000	3.00000	3.00000	5.00000	7.00000
vendor2	0.33333	1.00000	3.00000	3.00000	7.00000
vendor3	0.33333	0.33333	1.00000	7.00000	7.00000
vendor4	0.20000	0.33333	0.14286	1.00000	1.00000
vendor5	0.14286	0.14286	0.14286	1.00000	1.00000
sum	***2.00952***	***4.80952***	***7.28571***	***17.00000***	***23.00000***

The normalised relative weights were calculated by dividing each element of the matrix with the sum of its column, which is shown in table 4.11. The sum of each column is 1.

Table 4.11 Normalised relative weight of each vendor

	vendor1	Vendor2	vendor3	vendor4	vendor5
Vendor1	0.49763	0.623762	0.411765	0.294118	0.304348
vendor2	0.165877	0.207921	0.411765	0.176471	0.304348
vendor3	0.165877	0.069307	0.137255	0.411765	0.304348
vendor4	0.099526	0.069307	0.019608	0.058824	0.043478
vendor5	0.07109	0.029703	0.019608	0.058824	0.043478
sum	1	1	1	1	1

The normalised principal Eigen vector can be obtained by averaging across the rows

$$W = \frac{1}{5}\begin{Bmatrix} 0.49763+0.623762+0.411765+0.294118+0.304348 \\ 0.165877+0.207921+0.411765+0.176471+0.304348 \\ 0.165877+0.069307+0.137255+0.411765+0.304348 \\ 0.099526+0.69307+0.019608+0.058824+0.043478 \\ 0.07109+0.029703+0.019608+0.058824+0.043478 \end{Bmatrix} = \begin{bmatrix} 0.426325 \\ 0.253276 \\ 0.21771 \\ 0.058149 \\ 0.044541 \end{bmatrix}$$

The priority vectors for the criteria management and organisation (MNO) for five vendors as shown in below table 4.12.

Table 4.12 Priority vectors for the vendors with respect to MNO

Vendors	*Priority vectors*
Vendor 1	0.426325
Vendor 2	0.253276
Vendor 3	0.21771
Vendor 4	0.058149
Vendor 5	0.044541

In this research the preference pattern of the vendors based on management & organisation listed as above, which shows that "vendor 1" is the most preferred vendor in the criteria MNO. Similarly relative weightage of vendors with respect to each criterion are also calculated and shown in below table 4.13.

Table 4.13 Relative weightage of vendor vis-à-vis criteria

Row of average value (RAV)* →Summary of related weightage of vendor with respect to each criteria.					
	Vendor1	Vendor 2	Vendor 3	Vendor 4	Vendor 5
VCL	0.0436652	0.266744	0.217710	0.054678	0.040804
MNO	0.426325	0.253276	0.217710	0.058149	0.044541
TCL	0.410124	0.297000	0.017752	0.070533	0.046823
DCB	0.431124	0.125784	0.24742	0.11913	0.077758
PCP	0.084116	0.266244	0.146843	0.06388	0.038916
QLT	0.587148	0.08566	0.18924	0.08566	0.042608
FNC	0.388693	0.252776	0.252776	0.06940	0.036355
VCL	0.044065	0.113255	0.193146	0.177637	0.071897
SSP	0.416902	0.102721	0.274882	0.138559	0.066936
CST	0.508474	0.24500	0.1420500	0.062081	0.037896

Besides relative weight, the researcher has used Principal Eigen value to check the consistency, which is been discussed in the below section.

4.6 Consistency ratio

Principal Eigen value is obtained from the summation of reciprocal matrix (as tabulated in table 4.10) and priority vectors (as tabulated in table 4.12)

$$\lambda_{max} = 2.00952(0.426325) + 4.80952(0.253276) + 7.28571(0.21771) + 17.00(0.058149) + 23.00(0.044541)$$
$$= 5.373979$$

Saaty (2000) proved that for consistent reciprocal matrix, the largest Eigen value is equal to the size of comparison matrix, or λ_{max}= n. Then he gave a measure of consistency, called CI (Consistency Index) as deviation or degree of consistency using the following formula:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$

Thus here, λ_{max}= 5.373979 and the size of comparison matrix n= 5, thus the consistency index is:

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{5.373979 - 5}{4} = 0.093495$$

Prof. Saaty proposed that the use of this index by comparing it with the appropriate one. The appropriate Consistency index is called Random Consistency Index (*RI*). He randomly generated reciprocal matrix using scale $\frac{1}{9}, \frac{1}{8} \cdots, 8, 9$ (similar to the idea of Bootstrap) and get the random consistency index to see if it is about 10% or less. The average random consistency index of sample size 500 matrices is shown in the table 4.14.

Table 4.14 Random consistency index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Then, he proposed what is called CR (Consistency Ratio), which is a comparison, between Consistency Index and Random Consistency Index, or formula:

$$CR = \frac{CI}{RI}$$

If the value of CR is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, the subjective judgment needs to be revised. In the previous example, CI=0.093495 and RI for n=5 is 1.12, and then CR is:

$$CR = \frac{CI}{RI} = \frac{0.093495}{1.12} = 0.083477 = 8.3\% < 10\%$$

The CR calculation for other criteria are also calculated in the similar way and demonstrated in table 4.13.

Table 4.15 Consistency ratio calculation

CRITERIA	**CONSISTENCY RATIO**
Vendor credibility (VCL)	0.10
Management & Organisation (MNO)	0.06
Technical element (TCB)	0.04
Product stability (DCL)	0.07
Processes (PCP)	0.03
Quality (QLT)	0.07
Financial/commercial position (FNP)	0.08
Vendor culture (VCL)	0.05
Services/support (SSP)	0.02
Cost (CST)	0.09

Matrix algebra was used to obtain the final vendor score as in below:

Matrix algebra: Multiplying an n x n matrix by an n x 1 matrix gives an n x 1 matrix:

$$\begin{pmatrix} A & B & C & D \\ E & F & G & H \\ I & J & K & L \\ M & N & O & P \end{pmatrix} x \begin{pmatrix} W \\ X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} AW & BX & CY & DZ \\ EW & FX & GY & HZ \\ IW & JX & KY & LZ \\ MW & NX & OY & PZ \end{pmatrix}$$

As an example the vendor scores for vendor 1 is demonstrated in below table 4.16 where, vendor 1 enjoys 44% vendor selection, with top three criteria as management & organisation, product stability and quality.

Table 4.16 Vendor score

	Vendor 1		Rank
Management & organisation	0.1048(0.587148) =	0.06156	1
Product stability	0.1129(0.484116) =	0.05466	2
Quality	0.1196(0.431124) =	0.05157	3
Processes	0.1250(0.388693) =	0.04859	4
Cost	0.0833(0.508474) =	0.04237	5
Financial/commercial	0.0954(0.416902) =	0.03979	6
Technical elements	0.0954(0.410124) =	0.03914	7
Vendor culture	0.0847(0.044065) =	0.03731	8
Vendor credibility	0.0847(0.436652) =	0.03697	9
Services/support	0.0941(0.304685) =	0.02867	10
	Total =>	**0.44062**	
		44%	

Similarly, vendor selection score is calculated for the other four vendors and the ranking of each vendor is shown in below table 4.17.

Table 4.17 Vendor score for all the vendors

Vendors	***Score***	***Rank***
Vendor 1	0.44602	1
Vendor 2	0.20249	3
Vendor 3	0.21549	2
Vendor 4	0.09129	4
Vendor 5	0.04980	5

The pair wise comparisons of other criteria are shown in appendix III. Once the score analysis is done, based on the highest score, the vendor can be selected. Thus the vendor selection is achieved in this research by using SEM and AHP model and this chapter concludes with vendor selection using SEM and AHP. However, once a new model is developed, the sensitivity analysis should be done to validate the model; this has been discussed in the next chapter.

CHAPTER 5

RESULTS AND DISCUSSIONS

In the current global financial crisis, banks are seeking ways to cut costs amid falling revenue and rising cost of doing business. Since banks are mostly reliant on IT for the nature of their services, thus selection of the technology has become highly necessary. Any inaccurate selection will lead to numerous problems which affect the banks overall performance. The selection of the right vendor from the growing number of alternatives is complicated. Even though, quite a few vendor selection models are available in the literature, in this research, an attempt has been made to develop a composite model using SEM and AHP to attain the vendor selection score. This research focuses on the criteria that influence vendor selection and the model has been built based on those criteria. The new model has been validated using "what- if- analysis" technique which is discussed here in the following section.

5.1 Sensitivity analysis of the data

The model has been validated using the SA. It is a technique for systematically changing parameters in a model to determine the effects of such changes. "what- if- analysis" feature of Microsoft excel has been used to assess the model and to point out how sensitive is the proposed model is towards any small changes in the input variable. The use of this technique enables determination of the degree the proposed model is able to produce satisfactory output results when any change in the input variable occurs.

From the research completed, the rank of the vendors for a value between the lower and upper limits is arrived; any value that falls between the lower and upper limits is an acceptable value. The SA was completed to find out the change of rank in the vendors for global relative weightage 0.35, and 0.65; in addition to that relative weightage as 0.5 was also taken. In all three cases, the ranking of the vendors is found out to be the same. The analysis is shown in below table 5.1.

Table 5.1 Sensitivity analysis

	@ 0.35	@0.50	@0.65	Rank
Vendor1	0.4347	0.4461	0.4354	1
Vendor2	0.2077	0.1929	0.2090	3
Vendor3	0.2102	0.2115	0.2171	2
Vendor4	0.0948	0.1031	0.0911	4
Vendor5	0.0511	0.0546	0.0473	5

It is implied from the SA carried out, that any value that is between the lower and upper limits, does not affect the rank of the vendors. This proves the high sensitivity and reliability of the model, which makes it a suitable solution for vendor selection.

5.2 Conclusion

This research supports the mobile banking application vendor selection for the retail banks. The main focus of this research was to address two issues, vendor selection criteria relevant to mobile banking application, and development of a unique model for vendor selection. This research addresses a very important area in BFSI, where there is a gap in proper methodology of vendor selection. The technology vendors are the strategic partners of the bank, and thereby a proper methodology to select the right vendor, will not only help the banks secure the proper service, but will form a long term business alliance with the vendor.

The developed model in this research is a standard tool used for acquiring the numeric data to support the decision making to evaluate and select vendors. One of the most important contributions of this research is the construction of a model to understand the different vendor selection criteria related to technology vendor selection.

5.3 Study limitations

There are a number of limitations of this study of which we should be aware.

a. The critical business processes of the supply function of an organisation include vendor selection, negotiation of supply contracts, monitoring vendor performance and acting as an interface between an organisation and its vendors (Talluri & Sarkis, 2002). Within these core processes of purchasing, this study narrows its scope to focus upon the vendor selection process, which assists in maintaining effective buyer-supplier linkages. The results of this study may only reveal a partial picture of the current interaction between firms and their vendors.

b. The limitations of study are mainly related to the broadness of the topic under investigation, generalisability issues, lack of homogeneous organizational experiences, time constraints and the limited access to information. Because of the nature of business in banking industry, the direct access of data was an issue. Additionally mobile banking is a new technology; and therefore there are not many reference research papers or case studies are available on this topic. The sample size is another limitation of this study. The sample consists of banks and information technology vendors from Malaysia, Singapore, Philippine, India, Indonesia etc. The number of cases is limitation of this study. The cases consist of divisions of a bank. This bank is well established and large in size. The responses pertaining to few numbers of divisions do not provide sufficient basis to revise our theoretical model. The results from a larger and heterogeneous sample might provide a better basis to revise the theoretical model. However, seeing the nature of the questions spanning business processes, this number of cases is not considered entirely unusual.

We believe the results can still offer important guidelines for replicating the study over a larger sample of banks.

c. The use of the SEM requires much more formal training in statistics to be able to effectively use SEM software. Also, because of SEM is a theory-driven (confirmatory) technique, one must have a well-developed a priority model. Furthermore, the weak point of AHP is in determining the interrelationship among the factors. Although, the model is easy to use and use of the matrix algebra and Microsoft excel error during data entry and mistakes may occur. However, given the complexity and subject matter, this is considered reasonable.

d. The goal of using AHP is to determine relative ranking of vendors. To use it, decision makers must compare all pairs of criteria and vendors using a ratio scale. The accuracy of the comparison is dependent upon the information available to the decision makers and the depth of the decision makers understanding of the problem being considered. AHP method for vendor selection is very easy to understanding and accurate, but it is time consuming process because it involves comparison of all criteria to one another.

5.4 Recommendations

As banking and financial industry uses technology and business domain, thereby additional qualitative data using the developed model might provide better result in vendor selection. However, an extensive study is required to understand the business process and to identify the relevant criteria for vendor selection, which is a key factor in this research. A more simplistic approach involving both qualitative and quantitative data might help in real life scenario. While using SEM model, caution should be on data size. One study found that sample sizes in a particular stream of SEM literature averaged only 50% of the minimum needed to draw the conclusions the studies claimed. Overall, 80% of the research articles in the study drew conclusions from insufficient samples.

Sample size in SEM can be computed through two methods: the first as a function of the ratio of indicator variables to latent variables, and the second as a function of minimum effect, power and significance. Software and methods for computing both have been developed by Westland (2010).

Moreover, at present there is no known comprehensive procedure for enumerating all possible equivalent models for any SEM we may specify. To deal with this, we need to rely on information beyond the data to help choose the best model. This information may be from prior research knowledge about circumstances of data collection, managerial beliefs or intuition. Equivalence is not much different from knowing, which criteria are dependent of other and which are not. Most of the time, the data can not tell; the knowledge has to come from experience.

5.5 Direction for future work

There have been a growing demand and need for technology vendor in banking industry; thereby the selection process should consider all qualitative and quantitative criteria. More efforts should be made combining both criteria affecting vendor selection process in a rational and systematic way. Identifying more criteria in this regard and developing software for vendor selection could be the future work. Moreover, once the vendor has selected, the process must continue to evaluate the vendor's deliverables as per service level agreement and relationship development. The future research should also contain large sample size to verify the findings and to increase the external validity and generasibility of the findings.

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LIST OF PUBLICATIONS

i. Sarit Maitra and P D D Dominic, paper id 056 (2011). IT vendor selection using structural equation modeling & analytical hierarchy process. *International conference on software and information engineering (ICSIE)*, Kualalumpur.

ii. Sarit Maitra and P D D Dominic (2011). A hybrid model for IT vendor selection. *International management conference (IMaC)*, Taman Tamadun Islam, Kuala Terengganu, Malaysia, 16-17 April.

iii. Sarit Maitra and P D D Dominic (2011), paper id N128. IT vendor selection using structural equation modeling and analytical hierarchy process, *International conference on network communication and computer (INCC)*, March 19020, New Delhi, India.

iv. Sarit Maitra and P D D Dominic (2011), paper id. N115, Structural equation modeling approach for IT vendor selection. *International conference on network communication and computer (INCC)*, March 19-20, 2011.

v. Sarit Maitra and P D D Dominic (2011), paper id. C041. A hybrid model (SEM & AHP) to select IT vendor. *International conference on computer and communication devices (ICCD)*, April 1-3, Bali Island, Indonesia.

vi. Sarit Maitra and P D D Dominic (2011). IT vendor selection and SEM approach. *International conference on computer and communication devices* (ICCD), April 1-3, Bali Island, Indonesia.

vii. P D D Dominic and Sarit Maitra (2011). IT vendor selection model combining structural equation model and analytical hierarchy process. *PCO*, Dubai 1-3 June.

APPENDIX

Appendix I Survey on technology vendor selection

I am a research scholar pursuing research in IT vendor selection from University Teknologi of PETRONAS, Malaysia. Please take few minutes of your valuable time to go through the enclosed questionnaire and tell me about your experience on vendor selection process. The enclosed document contains the criteria and sub criteria were identified from different research and in discussions with the professionals in this area. These are relevant to technology vendor selection for mobile banking application in retain banking. You are requested to circle or highlight one of the seven ranges given from 1 to 7 against each criterion which you feel is appropriate and also state your comments on criteria and sub-criteria which you may find not sutable or relevant to the application. The values are in ascending order, i.e 7 is very important and 1 is very negligible. You may use any of the numbers in the middle as well as to show how strong your feelings are. With this survey, I would like to have your opinion and proceed further on my research activity.

7	VI	Very important
6	I	Important
5	SLI	Slightly important
4	NI/NN	Neither important/nor negligible
3	NTN	Not negligible
2	N	Negligible
1	VN	Very negligible

Criteria	*Sub criterion*	*VI*	*I*	*SLI*	*NI/ NM*	*N T N*	*N*	*V N*
Vendor credibility	Reputation in the market	7	6	5	4	3	2	1
	Reference clients	7	6	5	4	3	2	1
	Strategic directions	7	6	5	4	3	2	1
	Existing relationships	7	6	5	4	3	2	1
	Trustworthiness							
	Technical project management	7	6	5	4	3	2	1
Management & organisation	Physical size & Geographical presence	7	6	5	4	3	2	1
	Ethical standards	7	6	5	4	3	2	1
	Conflict management ability,	7	6	5	4	3	2	1
	Account management							
	Employees (educational qualifications of human resources	7	6	5	4	3	2	1
Technical element	Usability/ease of use	7	6	5	4	3	2	1
	User interface/visuals	7	6	5	4	3	2	1
	Flexibility,	7	6	5	4	3	2	1
	Functionality Extensible/customisable)	7	6	5	4	3	2	1
	Compatibility	7	6	5	4	3	2	1
	Security	7	6	5	4	3	2	1
Product stability	Performance levels	7	6	5	4	3	2	1
	Uptime percentage	7	6	5	4	3	2	1
	System usability	7	6	5	4	3	2	1
	Technology and innovativeness,	7	6	5	4	3	2	1
	Load/capacity	7	6	5	4	3	2	1
Processes	Internal process,	7	6	5	4	3	2	1
	Project management,	7	6	5	4	3	2	1
	Design/build process	7	6	5	4	3	2	1
	Training facility	7	6	5	4	3	2	1
Quality	Testing facility	7	6	5	4	3	2	1
	Product durability	7	6	5	4	3	2	1
	Performance and conformance to standards	7	6	5	4	3	2	1
	ISO/CMM certification status	7	6	5	4	3	2	1
	Total quality management	7	6	5	4	3	2	1
	Data Security	7	6	5	4	3	2	1

Criteria	*Sub criterion*	*VI*	*I*	*SLI*	*NI/ NM*	*NTN*	*N*	*VN*
Financial & commercial position	Sustainability	7	6	5	4	3	2	1
	Ownership structure/history	7	6	5	4	3	2	1
	Cash flow	7	6	5	4	3	2	1
	Intellectual property agreement,	7	6	5	4	3	2	1
	Non-disclosure agreement	7	6	5	4	3	2	1
	Financial record disclosure with growth rate	7	6	5	4	3		
	Warranties and claim policies	7	6	5	4	3	2	1
Vendor culture	Professionalism	7	6	5	4	3	2	1
	Flexibility & commitment						2	1
	Open/friendly	7	6	5	4	3	2	1
	Integrity	7	6	5	4	3		
	Understanding the business goals & environment	7	6	5	4	3	2	1
	Proactiveness	7	6	5	4	3	2	1
Services & support	After sales service						2	1
	Technical support level	7	6	5	4	3	2	1
	Sales person/ account manager's competence	7	6	5	4	3	2	1
	Documentation	7	6	5	4	3		
Cost	One time (set-up, configuration, development)	7	6	5	4	3		
	On going (maintenance, support, licensing, data migration, training)	7	6	5	4	3	2	1
	Total cost of ownership	7	6	5	4	3	2	1

Appendix II Amos analysis on critical ratio and p-Value

	Sub criteria	Factor estimate	Error variance	t-value	p-value	CR	Evidence
H_1 (VCB)	Reputation in the market (a_1)	0.84	1.10	9.13	0.012	2.510	Supported
	Reference clients (a_2)	1.05	0.87	9.62			
	Strategic directions (a_3)	0.92	0.73	9.19			
	Existing relationships (a_4)	0.86	0.69	9.93			
	Trustworthiness(a_5)	1.09	0.93	7.66			
	Technical management (a_6)	0.61	0.71	7.47			
H_2 (MNO)	Physical size(a_7)	1.02	0.77	8.12	0.043	2.024	Supported
	Ethical standards(a_8)	0.74	0.95	8.44			
	Conflict management ability (a_9)	0.93	1.05	9.34			
H_3 (TCB)	Usability (a_{10})	0.68	1.24	7.07	0.045	2.001	Supported
	Flexibility (a_{11})	0.97	1.51	5.69			
	Compatibility (a_{12})	0.78	1.13	6.98			
	Security(a_{13})	0.77	1.05	9.34			
H_4 (DCB)	Performance levels (a_{14})	0.78	0.71	7.47	0.030	2.165	Supported
	Uptime percentage(a_{15})	0.97	0.74	10.06			
	Technology and innovativeness(a_{16})	0.61	0.78	8.50			
	Load/capacity (a_{17})	0.88	0.88	8.12			
	System usability (a_{18})	0.92	1.07	5.86			

Appendix II continued

	Sub criteria	Factor estimate	Error variance	t-value	p-value	CR	Evidence
H_5 (PCP)	Internal process(a_{19})	0.65	0.99	10.04	0.023	2.269	Supported
	Project management(a_{20})	0.74	1.17	7.04			
	Design/build process(a_{21})	0.80	0.89	8.39			
	Training facility(a_{22})	0.84	0.95	8.44			
H_6 (QLT)	Testing facility (a_{23})	0.91	0.80	0.48	0.005	2.807	Supported
	ISO/CMM certification(a_{24})	0.86	0.92	8.70			
	TQM(a_{25})	1.06	0.38	12.78			
	Product performance/conformance standards(a_{26})	0.94	0.49	11.25			
H_7 (FNP)	Sustainability(a_{27})	0.81	0.57	9.46	0.010	2.125	Supported
	Ownership structure(a_{28})	0.87	0.59	9.50			
	Cash flow(a_{29})	0.65	0.54	10.09			
	Intellectual property agreement(a_{30})	0.91	0.69	9.76			
	Non-disclosure agreement(a_{31})	0.90	0.70	7.88			
	Financial record disclosure (a_{32})	1.06	0.60	11.30			
	Warranties & claim policies(a_{33})	0.93	0.85	9.68			
H_8 (VCL)	Professionalism(a_{34})	0.55	0.95	6.01	0.039	2.259	Supported
	Flexibility(a_{35})	1.26	0.38	13.67			
	Integrity(a_{36})	0.90	1.05	9.34			
	Understanding business goals(a_{37})	0.86	0.87	9.11			

Appendix II continued

	Sub criteria	Factor estimate	Error variation	t-value	p-value	CR	Evidence
H_9 (SSP)	After sales service(a_{38})	0.91	1.34	8.10	0.028	2.030	Supported
	Technical support(a_{39})	1.35	0.82	12.15			
	Availability(a_{40})	0.82	0.78	9.10			
H_{10} (CST)	One time (a_{41})	1.15	0.83	10.92	0.015	2.014	Supported
	Ongoing (a_{42})	1.24	0.39	13.20			
	Data migration /training(a_{43})	1.17	0.91	10.75			

Appendix III

Pair wise comparisons-VCB

Vendor Credibility					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	7	5	7	7
Vendor 2	1/7	1	1/3	1	3
Vendor 3	1/5	3	1	3	5
Vendor 4	1/7	1	1/3	1	3
Vendor 5	1/7	1/3	1/5	1/3	1

Pair wise comparisons-TCB

Technical capability					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	2	3	5	5
Vendor 2	½	1	2	5	7
Vendor 3	1/3	½	1	3	5
Vendor 4	1/5	1/5	1/3	1	2
Vendor 5	1/5	1/7	1/5	½	1

Pair wise comparisons-DCB

Delivery capability					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	4	3	5	7
Vendor 2	¼	1	3	5	7
Vendor 3	1/3	1/3	1	3	5
Vendor 4	1/5	1/5	1/3	1	2
Vendor 5	1/7	1/7	1/5	½	1

Pair wise comparisons-PCP

Processes					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	2	2	5	7
Vendor 2	½	1	1	5	7
Vendor 3	½	1	1	5	7
Vendor 4	1/5	1/5	1/5	1	3
Vendor 5	1/7	1/7	1/7	1/3	1

Pair wise comparisons-QLT

Quality					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	3	2	5	5
Vendor 2	1/3	1	1/3	2	1
Vendor 3	½	3	1	2	3
Vendor 4	1/5	½	½	1	3
Vendor 5	1/5	1	1/3	1/3	1

Pair wise comparisons- FNP

Financials & commercials					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	5	3	2	3
Vendor 2	1/5	1	1/3	1	2
Vendor 3	1/3	3	1	3	5
Vendor 4	½	1	1/3	1	3
Vendor 5	1/3	½	1/5	1/3	1

Pair wise comparisons-VCL

Vendor culture					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	5	3	2	5
Vendor 2	1/5	1	1/3	1	2
Vendor 3	1/3	3	1	1	2
Vendor 4	½	1	1	1	3
Vendor 5	1/5	½	½	1/3	1

Pair wise comparisons-SSP

Services & support					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor 1	1	1	1	5	7
Vendor 2	1	1	1	3	7
Vendor 3	1	1	1	5	7
Vendor 4	1/5	1/3	1/5	1	3
Vendor 5	1/7	1/7	1/7	1/3	1

Pair wise comparisons-CST

Cost					
	Vendor 1	Vendor 2	Vendor3	Vendor 4	Vendor 5
Vendor1	1	5	3	5	7
Vendor 2	1/5	1	3	5	7
Vendor 3	1/3	1/3	1	3	5
Vendor 4	1/5	1/5	1/3	1	2
Vendor 5	1/7	1/7	1/5	½	1